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DEVELOPMENT OF A FIBER OPTICS CONNECTOR BASED ON
MIL-C-38999 SERIES IV(U) G AND H TECHNOLOGY INC SANTA
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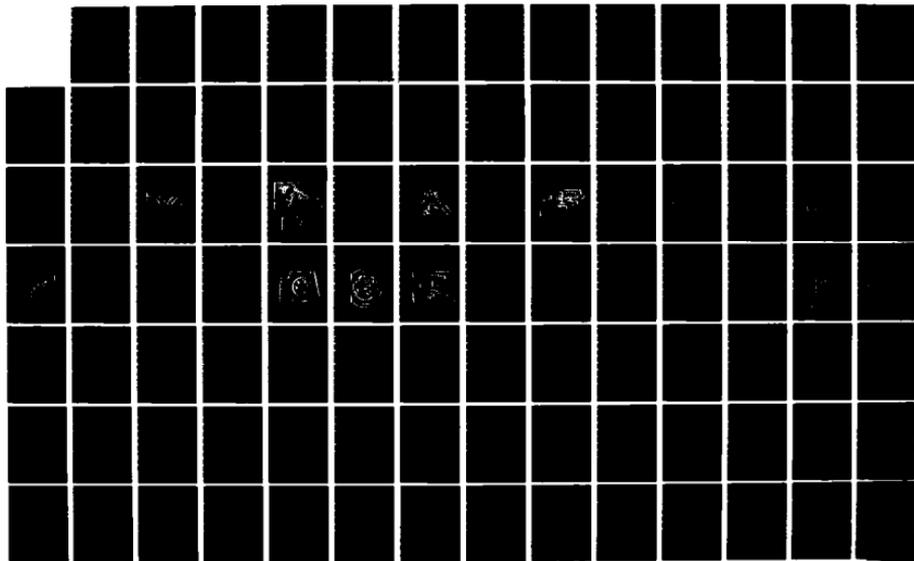
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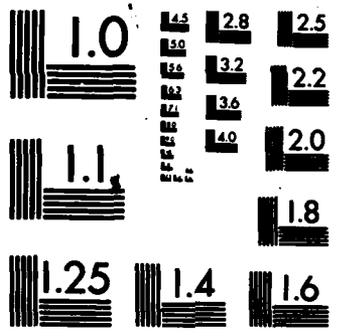
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FINAL TECHNICAL REPORT

OCTOBER, 1982



AD A137597

**DEVELOPMENT
OF A FIBER OPTICS CONNECTOR
BASED ON MIL-C-38999
SERIES IV**

**G & H TECHNOLOGY
SANTA MONICA, CALIFORNIA**

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**APPLIED RESEARCH DEPARTMENT
NAVAL AVIONICS CENTER
INDIANAPOLIS, INDIANA**

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changes or modifications to the connector. Contact termination requires mechanical crimping and no epoxy or index matching fluids. The removable electrical hood element is replaced with a unique fiber optic contact injection-molded alignment sleeve with the same envelope dimensions as the electrical hood element. Development work included design and fabrication of associated fiber optic contact assembly tooling, optical fiber end preparation tooling, backshell investigation, and environmental and mechanical testing in thermal shock, humidity, salt spray, sand and dust, vibration and durability. Insertion loss testing shows expected dB losses to be under 2dB. Higher losses occurred occasionally probably due to inconsistencies in the early stage of assembly tooling development.

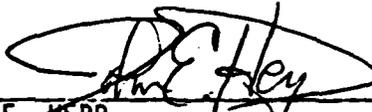


FOREWORD

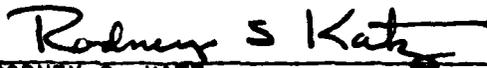
This report describes the development and testing of a multichannel MIL-C-38999, Series IV fiber optics connector. The quick-disconnect coupling mechanism is produced by G&H Technology, Inc., Santa Monica, California, and is marketed under the trade name of Breech-Lok. Specific developments include techniques and tools to strip, scribe/break and crimp terminate an optical fiber/cable. The contact assemblies are spring loaded and are held in alignment by a newly-developed captive bushing. This report also includes results of a series of MIL-specified tests which demonstrate the ruggedized construction of the connector.

This development was accomplished by G&H Technology for the Naval Avionics Center (NAC) under Contract No. N00163-81-C-0062. The principal investigator was Mr. Douglas A. Parker of G&H. Funding for this effort was provided by the Naval Air Systems Command (NAVAIR), Washington, DC. The NAVAIR technology administrator for this project was Mr. Andrew Glista, Code AIR-332C. The program manager at NAC was Mr. Rod Katz, Code 811. NAC project engineers for the initial and final phases of development were Mr. John Herp and Dr. Sukhbir Singh, Code 813.

This report has been reviewed and is approved for publication.



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EXECUTIVE SUMMARY

The basic objective of this development program was to produce fiber optic contacts to be inserted in the MIL-C-38999 Series IV Breech-lok connector without modifying the fully qualified connector. This objective was met with production of functional prototype spring loaded contacts which replace size 12 electrical contacts (MIL-C-39029) without any change to the connector itself. The developed fiber optic socket and pin contacts are identical. These contacts are inserted and removed, employing the same standard tool (NAS 1664-12) used with the Series IV electrical contacts. The fiber optic contacts will accommodate either 50/125 micron or 100/140 micron fiber utilizing a three-rod alignment system. The functional prototype Breech-lok connectors developed are shell size 17 with six contacts per connector offering a choice of any combination of electrical and fiber optic contacts.

There are several reasons for choosing to develop fiber optic capability for the qualified MIL-C-38999 Series IV Breech-lok connector. The quick 90° rotation of the coupling mechanism draws the socket and pin inserts smoothly together with no overtravel. The connector plug housing always goes to the same location with every mating and the completion of mating is positively indicated by the audible click. With this highly controlled, repeatably accurate connector mating, the spring-loaded fiber optic contacts are assured of precise axial travel and a positive interface every time.

Due to the desirability of achieving true field termination and repair procedures, the connector requires no epoxy, index matching fluids, ultraviolet curing or polishing, all of which can be potential problems in the field. Contact components are corrosion-resistant beryllium copper and stainless steel, joined in an injection-molded thermoplastic polyester alignment bushing. This contact system requires crimp termination using tooling generated specifically for this application. The crimping operation first positions the fiber then fixes it permanently within the contact.

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Dissatisfaction with currently marketed cleaving tools prompted development of a 360° scribe cleaving tool which repeatably produces cleaves of less than 1° deviation from perpendicularity to the fiber central axis. This tool establishes proper stripped fiber length and mirror finish fiber end quality during the cleaving operation.

Testing of the connector system was carried out in vibration, thermal shock, durability, humidity, salt spray and sand and dust. These tests were conducted in accordance with EIA FOTP's (fiber optic test procedures) when applicable and generally at the levels required for Series IV qualification with reduced times due to scheduling. Results indicate that the fiber optic connector performs well under adverse conditions. Maximum change in optical transmittance due to random horizontal and vertical vibration was -0.5 dB, in thermal shock -0.2 dB at -55° and -0.4 dB at +85°C, in durability (500 matings and unmatings) -0.2 dB, in humidity -0.3 dB, in salt spray -0.8 dB (3 open channels) and in sand and dust -0.5 dB.

A backshell is required to protect cable with the Series IV connector. A stock backshell was purchased for protection of the rear of the connector and cable entry area during the test program. The fiber optic cable used in this development effort was Pirelli 5050 ST with 100/140 micron graded index glass fiber and Kevlar strength member reinforcement. It was recognized that a backshell suitable for use with this cable, the Series IV connector and the developed fiber optic contacts must provide a service loop and strength member tie-off at the rear of the backshell. The stock backshell provided these features to a limited degree, restricting prototypes to 3 active channels.

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Future extensions of this reported effort will include:

- improvement in contact components for added strength, reliability and cost reductions
- cleave and crimp tool improvement especially in field suitability
- development of a field kit, containing all tooling required for installation, maintenance and repair, including investigation of cleaning and inspection techniques
- additional backshell design and development to accommodate service loop, strain relief tie-off and cable clamping characteristics
- investigation, design and development of strength member tie-off at the rear of the contact
- contact capability for size 16 and size 20 fiber optic terminations
- investigation of terminating alternative fiber sizes and types

NAVY CONTRACT NOO163-81-C-0062 (NAC)

1. General Overview

1.1 Objective

The objective of this effort is to develop a fiber optic Breech-Lok connector. This includes development, fabrication and evaluation of prototype fiber optic Breech-Lok Connectors. Design requirements require use of 140 micron single channel fiber optic graded index cable connected with a six channel shell size 17 connector.

In addition, the effort is to include associated development of repeatable fiber preparation techniques, repeatable crimp termination of fibers and investigation of contact termination and backshell termination techniques to establish a set of design parameters.

1.2 Development

A working fiber optic connector has been developed including the required associated tooling for contact assembly and fiber end preparation and use was made of a stock backshell for fiber optic cable clamping and fiber protection to investigate the satisfying of the particular backshell requirements. Figure 1 shows the development schedule which took place in implementing the program.

1.3 Test Program

The series of mechanical and environmental tests scheduled for evaluation of the performance of the fiber optic Breech-Lok connector is shown in Figure 2 with actual testing dates.

2. Background

2.1 Design Considerations

The successful application of fiber optic technology requires consideration of several critical limitations which affect the attenuation of signal transmission in optical fibers. A low loss, minimum attenuation signal coupling is the goal in fiber optic connectors.

2.1.1 Fiber end finish. The condition of the prepared fiber end face, both the surface smoothness and perpendicularity to the fiber axis will influence signal attenuation. A mirror finish, 90° perpendicularity and absence of foreign particle contamination are desired.

2.1.2 Fiber end separation. The gap between fiber ends will degrade the signal transmission increasingly as the distance between fiber ends increases as shown in Figure 3a, typical of step index glass fibers (shown for clarity to illustrate the phenomenon). Semi-graded index Galite 5050ST(NA=0.3) fiber used in this effort behaves similarly.

FIGURE 1.

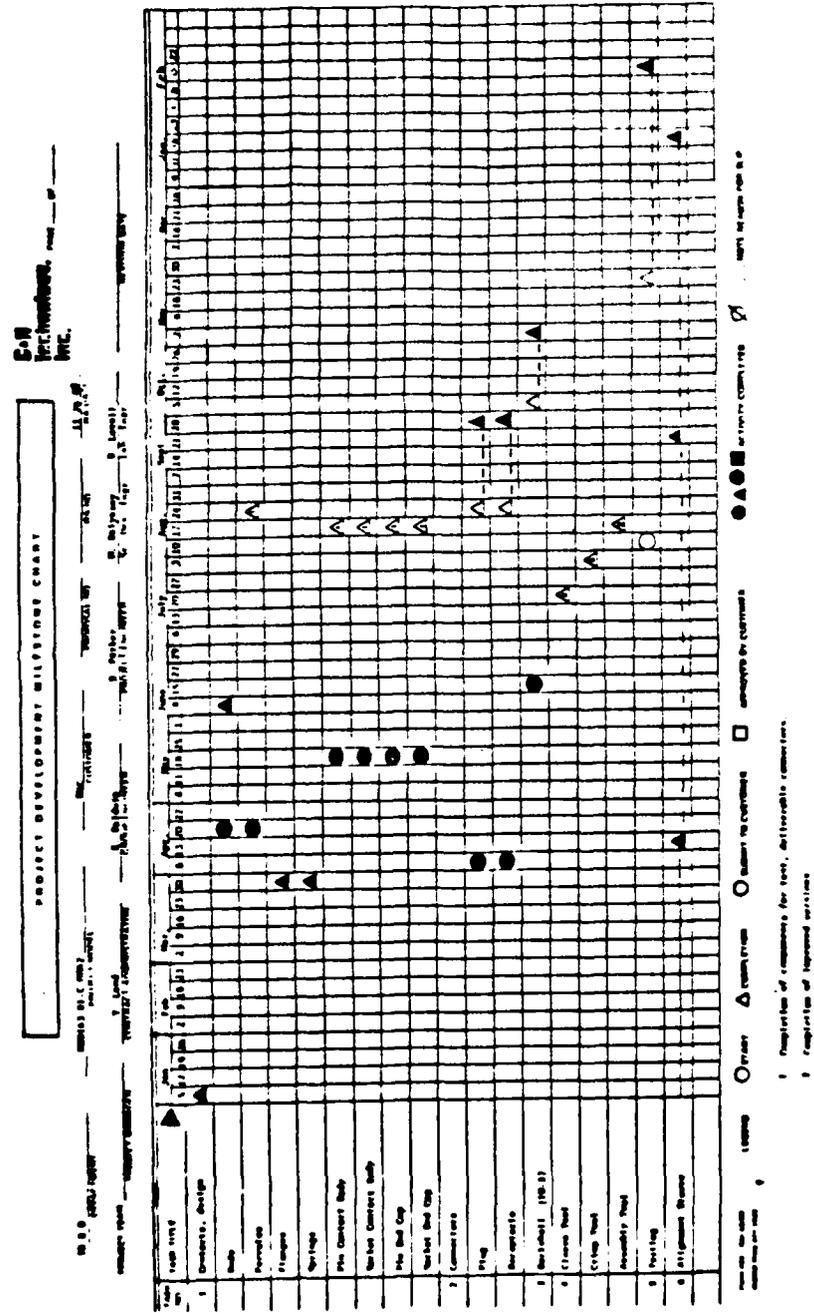


FIGURE 2.

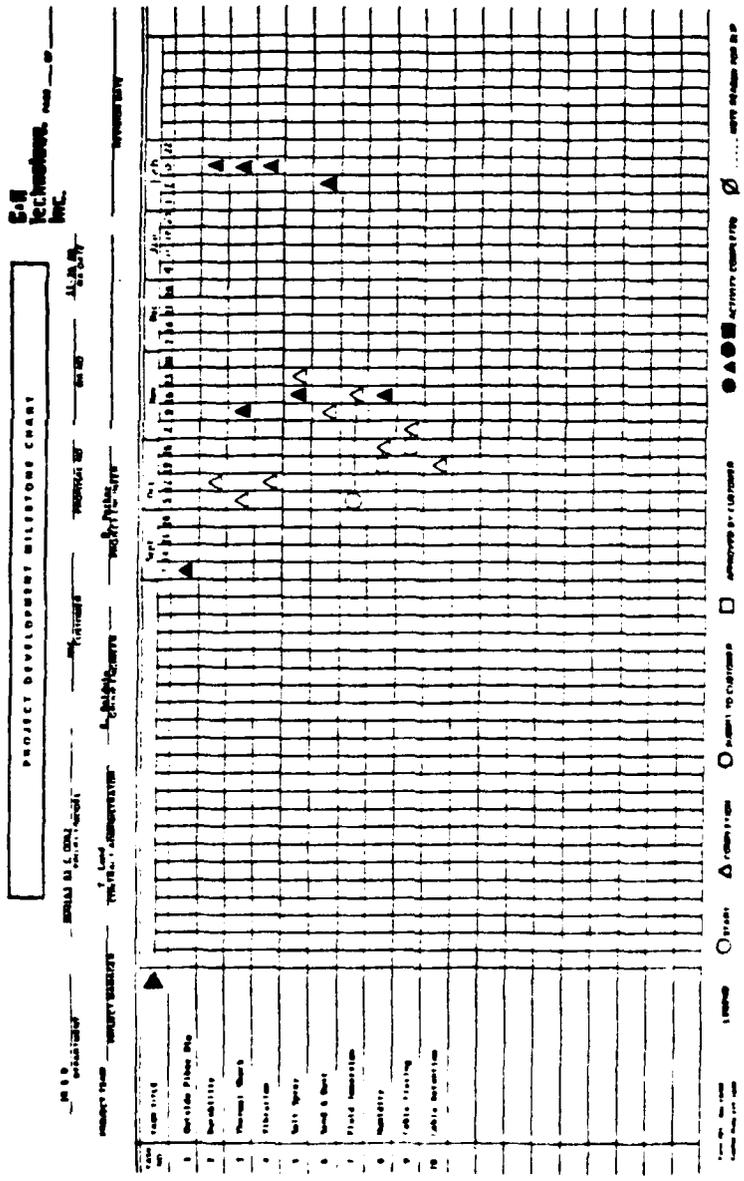
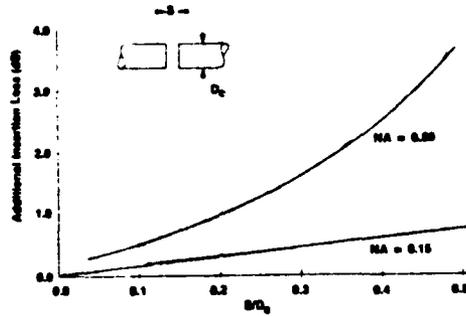
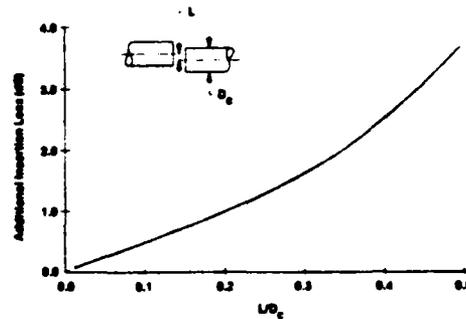


FIGURE 3.

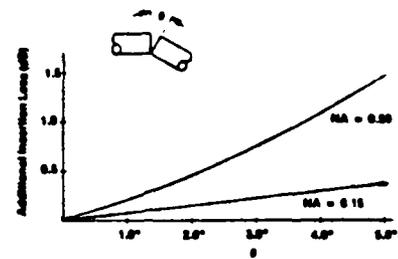
Typical Loss Factors
Step Index Glass Fibers



The Effect of End Separation(s) of the
Fiber Cores (D_c) on Connector Insertion Loss.



The Effect of Lateral Misalignment of the
Fiber Cores (D_c) on Connector Insertion Loss.



The Effect of Angular Misalignment (θ)
of the Fibers on the Connector Insertion Loss.

2. Background (Cont'd)

2.1 Design Considerations (Cont'd)

2.1.3 Fiber alignment

2.1.3.1 Axial or lateral misalignment. The misaligning of fiber axes can produce the largest loss contributions in fiber optic interconnections. Figure 3b shows that a mis-match of 0.1 core diameters causes a loss of .5dB for step index fibers. For a 140 micron core, this represents an offset of 14 microns (.0006 in.) and the Galite 5050ST semi-graded index fiber behaves in a similar manner.

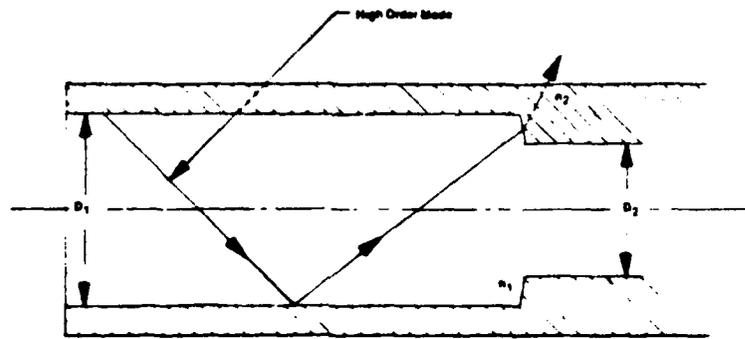
2.1.3.2 Fiber end angular misalignment. If the joined fiber axes are misaligned angularly, there is additional insertion loss in the interconnection. (Figure 3c shows typical behavior for step index fibers. Semi-graded index fibers behave similarly).

2.1.4 Diameter mis-match. Figure 4 illustrates the losses encountered when different diameter fibers are coupled. Of course, the direction of light transmission relative to the increase or decrease of fiber diameters will determine the effect of this transition. Figure 4a shows the most adverse situation created by diameter size variations at an optical interface or within a length of fiber. Again, this illustration shows step index fibers for clarity of the phenomenon.

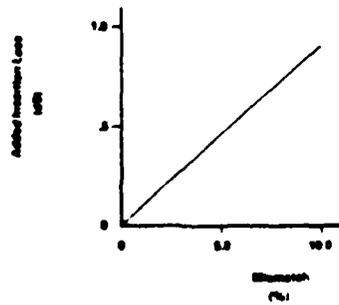
2.1.5 Other mechanisms which contribute to attenuation. Fresnel loss is due to the reflections occurring with the change of index of refraction when light passes from one fiber to air and back into the coupled fiber. The Fresnel loss can be minimized with a fluid medium or "index matching" fluid in place of the air interstice, but this is often a messy, potentially contamination-inducing situation. Microbending due to cabling process inconsistencies and numerical aperture mis-match can also degrade signal transmission.

2.1.6 The wavelength of light used, (Figure 5), the system bandwidth requirements and data rate of signal transmission are all factors which influence the selection of fiber optic cable to be used for optimum signal transmission.

FIGURE 4.

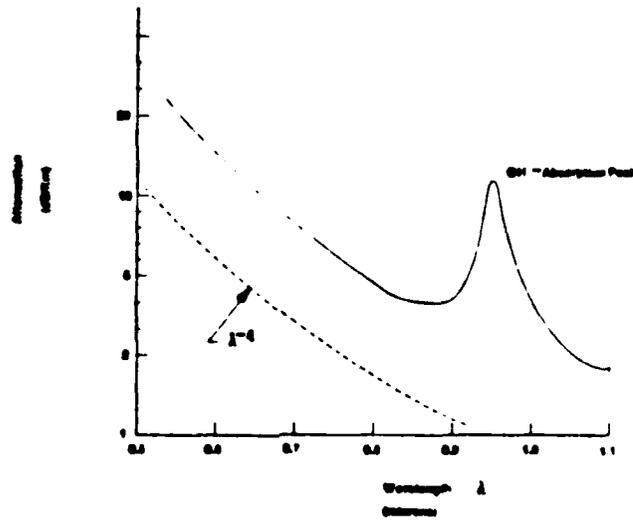
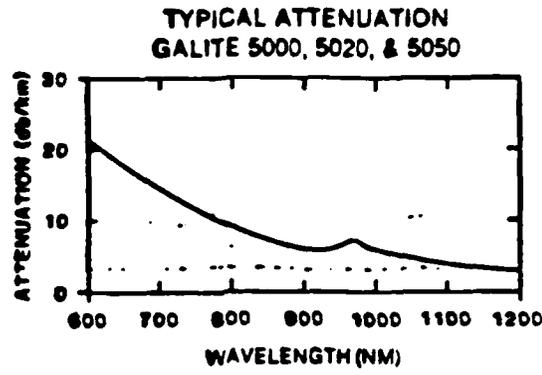


Effect of Diameter Variations on Ray Transmission at Transition High Order Mode Escapes into Cladding.



The Effect of Diameter Mismatch and NA Mismatch on Connector Insertion Loss.

FIGURE 5.



Typical Attenuation Characteristics — Silica Fibers

3. Connector Design

3.1 Design parameters.

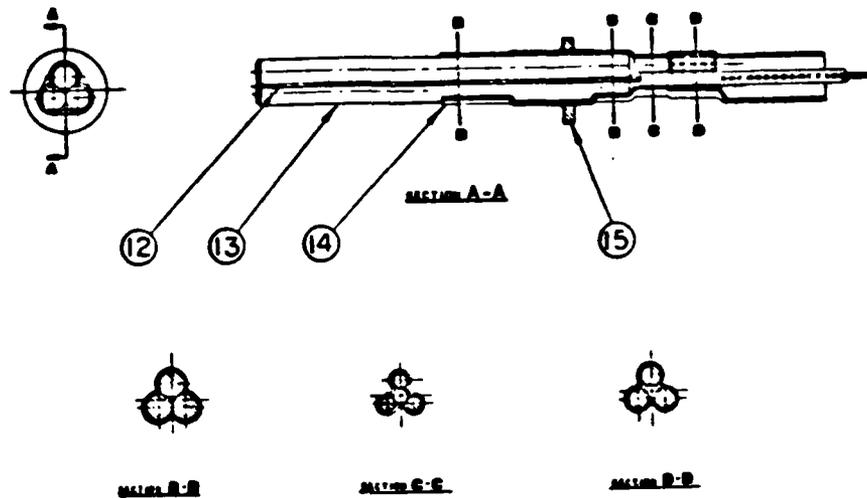
The design of fiber optic contacts at G & H Technology began in 1979 with the following basic criteria of design:

- replace MIL-C-38999 electrical contacts with fiber optic contacts without modifying the existing connector hardware, seals, retaining clip, etc., in the standard Breech-Lok connector.
- use standard electrical contact insertion, removal tools.
- contacts should be field terminable; cable preparation means, contact crimp tooling and insertion means should be provided for ease of assembly and installation of contacts in the connector.
- minimum attenuation of connected optical waveguide signal.

3.2 Contact

3.2.1 Contact design. The contact concept developed in 1979 uses a 3 rod sub-assembly providing axial support and accurate positioning of the stripped fiber within the precise interstice formed by the sub-assembly of the 3 rods. Figure 6A shows the 3 rod arrangement. The stainless steel rods are designed with serrations (See D-D in section A-A, Figure 6A) which "bite" into the 140 micron fiber primary resilient double buffer coating (see Figure 7) to maintain the fiber end face location as established in fiber installation and contact crimping. The axial alignment is maintained on the stripped bare fiber and not by the tight buffer coat. A formed copper alloy ferrule has a copper alloy flange (Item 15, Figure 6A) brazed into place. The sub-assembly is fixed permanently by means of the ferrule, which is fitted over the three rods and the positioned fiber, then crimped into place. Figure 6A shows the details of the crimping forms at each section of the three rod sub-assembly. Crimping is accomplished with a tool developed for this operation. The flange provides a stop for the spring (Item 7, Figure 8). The sub-assembly is then contained within a contact body by means of a brass end cap held in place by four contact body tines bent into place. The assembly is now a spring-loaded fiber optic contact with a fiber accurately positioned for coupling to a like contact (Figure 6B). A silicone plug is provided for fiber support, initial aligning and protection at the tail of each contact.

FIGURE 6.



CRIMPED CONTACT ASSEMBLY

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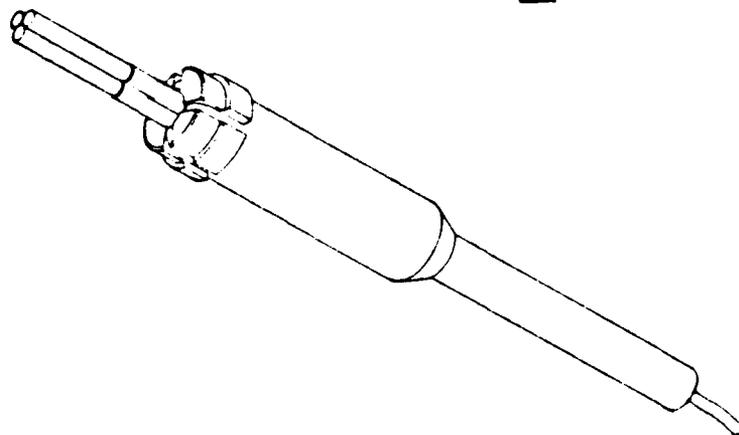


FIGURE 7
CABLE STRUCTURE,
GALITE 5050 ST

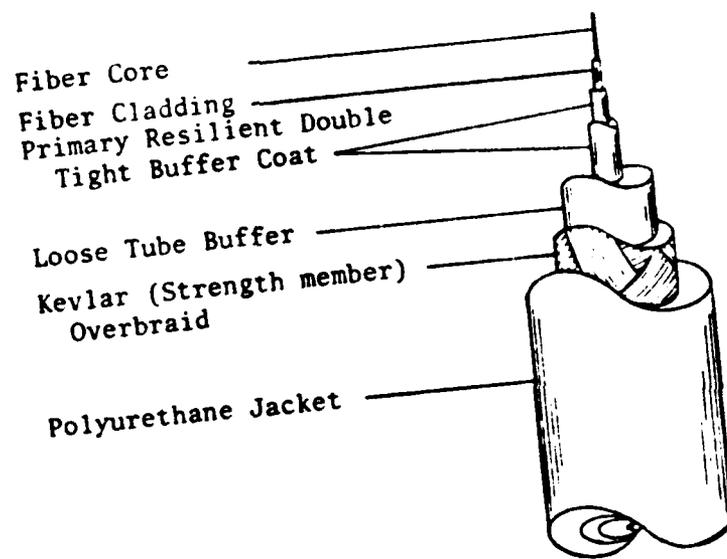
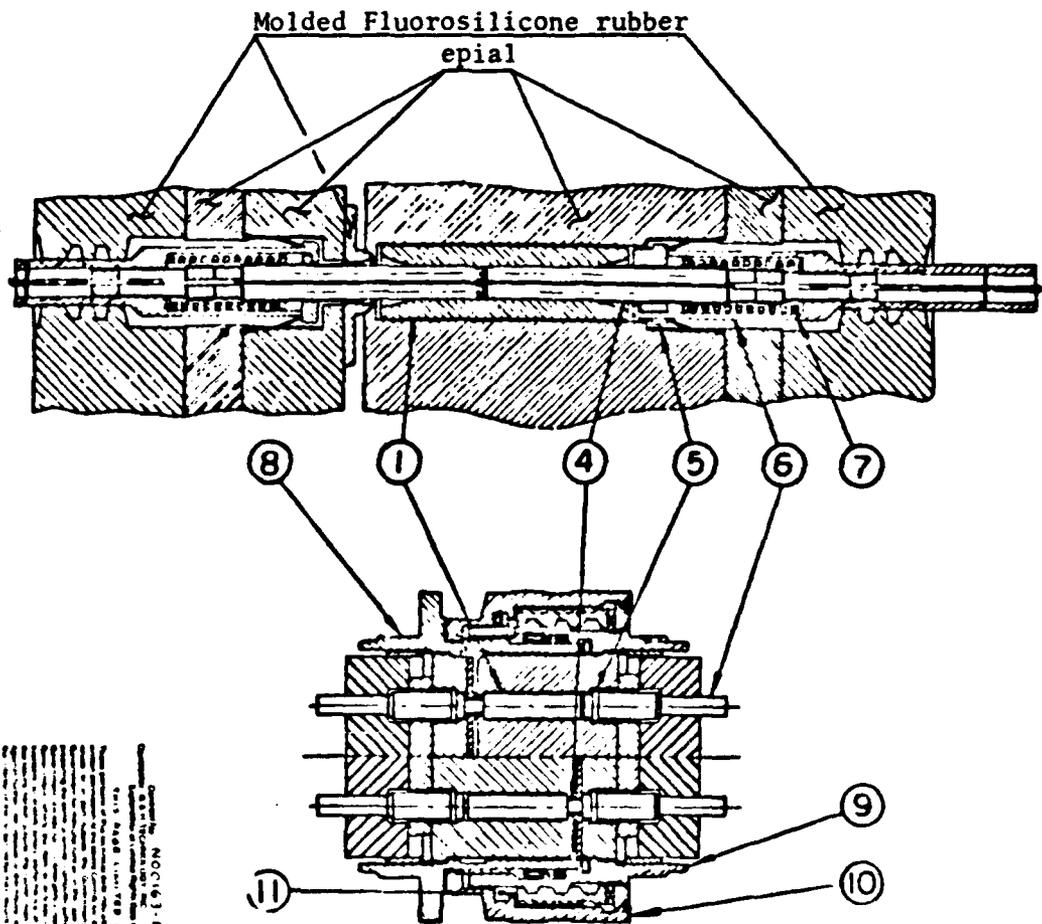


FIGURE 8.



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FIBER OPTIC BREACH-LOK CONNECTOR

3. Connector Design (Cont'd)

3.2 Contact (Cont'd)

3.2.2 Contact Insertion and Removal. Figure 9 shows contact insertion and removal using standard Breech-Lok MS electrical contact insertion and removal tooling. The contact cannot be pulled out by means of the fiber at the tail of the contact but rather it should be pushed out by a special tool from the front. (The special tool will push out the contact without disturbing fiber position or degrading the fiber end face quality.)

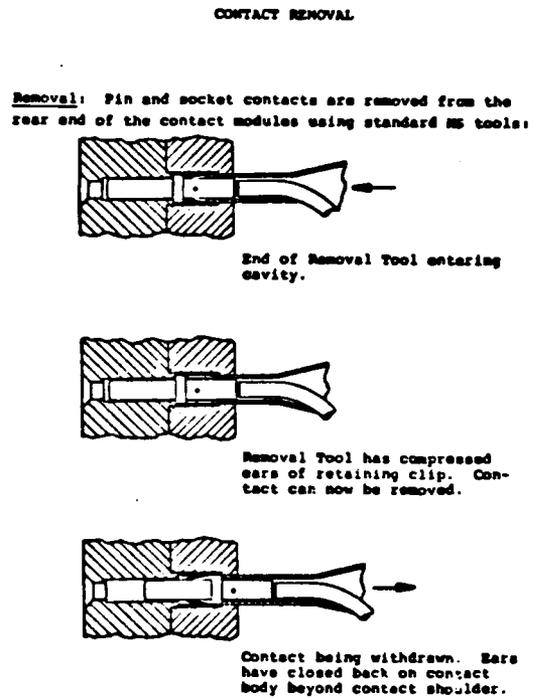
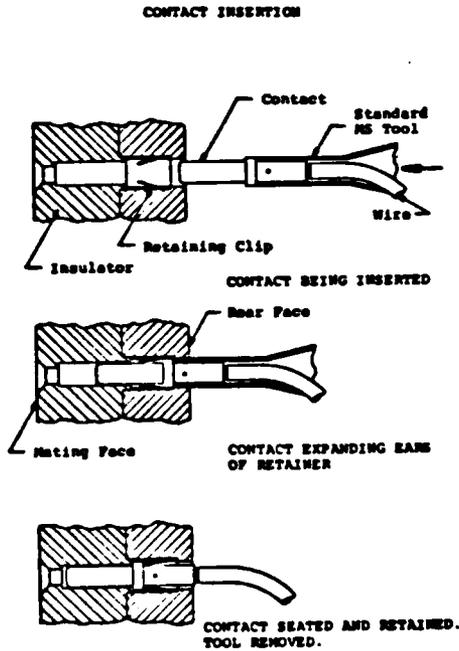
3.3 Alignment Member Design

3.3.1 Providing and maintaining axial and angular alignment of the two fibers being joined in a line connection is critical (as discussed in 2.1). The positioning of the fibers by the precision three rod assemblies is only as accurate as the axial alignment of those rod assemblies. The alignment sleeves developed at G & H Technology (Item 1, Figure 8) conform to the envelope dimensions of the standard electrical Breech-lok hooded contact insert allowing normal insertion into the socket assembly of the connector using standard electrical contact hood element installation and removal tooling. The developed sleeves were of injection molded polyphenylene sulfide. The retention and positioning of the alignment sleeves is accomplished with the same internal connector clips which hold the electrical hood element in position. Consideration has also been given to using a formed metallic circumferential spring sleeve. The basic criteria in alignment is to provide a slight interference fit around the three-rod assembly contacts while minimizing wear (and thus possible particulate contamination), maintaining the precise inside diameter after repeated matings and unmatings and maintaining the inside diameter after undergoing the adverse conditions of the environmental and mechanical testing. The alignment sleeves shown in Figures 10 and 11 show alternatives which should provide the required features when molded of the proper material. A new, all metal bushing is also in the conceptual stage of development.

3.4 Cable, Stripping

3.4.1 The cable required for this effort is Galite 5050ST 140 micron semi-graded index Kevlar reinforced jacketed fiber optic single channel cable. Also used was Galite 5050ST special cable with fiberglass reinforcement. Both cables had polyurethane jacket (Fig. 7) removed with a rotating blade cutter tool. The Kevlar was set aside for later backshell tie off. The loose tube buffer was removed with a plier type stripper using a sliding motion as was the primary double buffer resilient coating. This primary buffer was stripped to a predetermined length in preparation for use in the cleave tool.

FIGURE 9

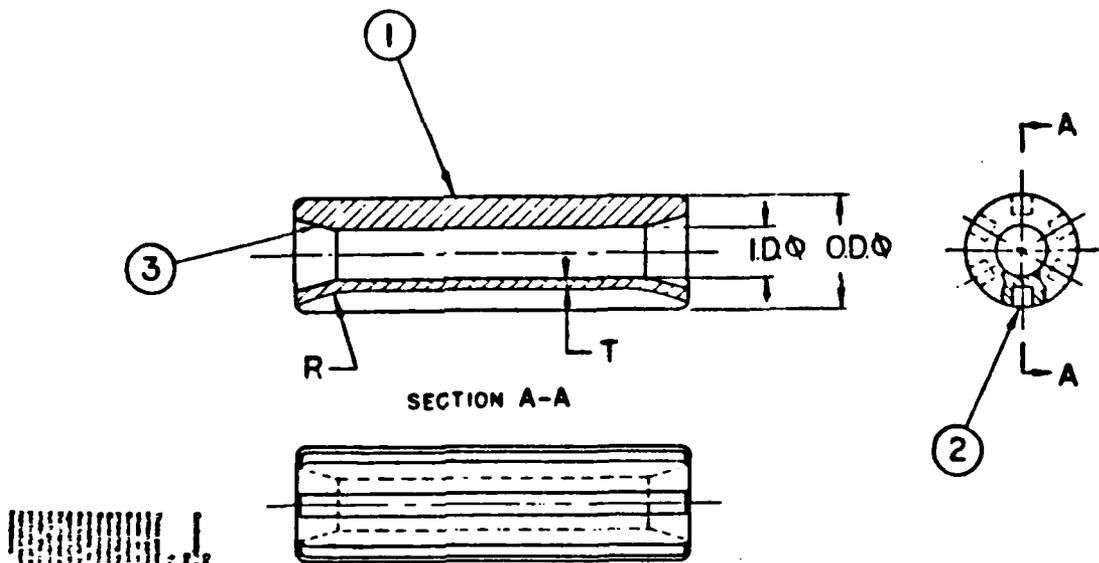


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 Contractor: G & H TECHNOLOGY, INC.
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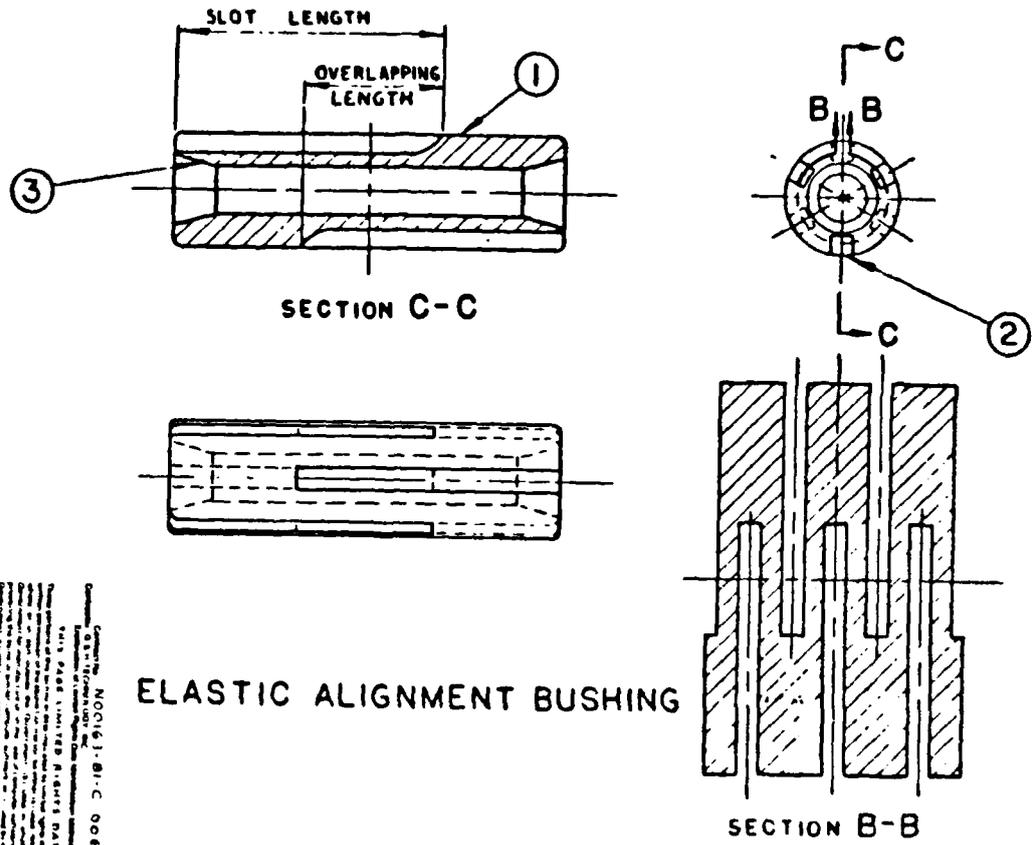
FIGURE 10.



ELASTIC ALIGNMENT BUSHING

Quantity: 100163-81-C-0062
Part Name: Elastic Alignment Bushing
Part Number: 100163-81-C-0062
Drawing Date: 10/17/78
Drawing By: J. J. [unreadable]
Drawing Check: [unreadable]
Drawing Appr: [unreadable]
Drawing Rev: [unreadable]

FIGURE 11.



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3. Connector Design (Cont'd)

3.5 Backshell Design

3.5.1 It is necessary to provide protection of the stripped fibers, a service loop area to house excess fiber available for potential contact replacement, and to provide strain relief of the cable utilizing the Kevlar aramid strength member (Figure 12) ensuring that no tensile loading will be applied to the fibers.

3.6 Tooling Design

3.6.1 Cable stripping tooling is necessary for field preparation of cable ends, exposing the fiber for end preparation.

3.6.2 Fiber end preparation tooling is necessary to provide field terminable, high quality fiber end finish for optimum connector performance

3.6.3 Crimp tooling is required for field termination of the contact on the prepared fiber end. Also required is bend tooling for final assembly of the spring-loaded contact.

3.6.4 Contact insertion tooling is required for field installation of the contacts and alignment sleeve into the connector. This tooling is the standard electrical contact installation/removal tooling.

4. Program

4.1 Contacts

4.1.1 Components: All components were completed in sufficient quantity to assemble the contacts required for the test program. This includes stainless steel alignment rods, extruded copper-alloy ferrules, brass contact bodies and end caps, coil compression springs, spring positioning flanges, and silicone rubber sealing plugs at the tail of the contacts.

4.1.2 Assembly: Brazing of the flange to the ferrule was done by hand assembly. The assembly of the contact is done with a tool which bends the four tines over to complete the spring-loaded contact assembly.

4.2 Alignment Member

4.1.1 Component: Injection-mold tooling was used to produce the precision alignment sleeves. Parts were run November 3, and fine modification of tooling was completed by December 18, 1981. This was a revised schedule, with slippage caused by vendor die-making difficulties. The fine modification included a slight (.0001) inside diameter decrease to provide a more snug, compressive precise alignment. The sleeves used in testing were of Ryton Br-56 polyphenylene sulfide.

4. Program (Cont'd)

4.3 Cable

4.3.1 The cable called for by contract, Galite 5050 ST with Kevlar reinforcement, was used for all the environmental tests run. In addition, a sample quantity of Galite special 5050 ST cable with fiberglass reinforcement was supplied to G & H by NAC and used in the first three connector tests (See 4.6.3). Both cables have desirable features but more testing is necessary to evaluate fully. The connector assembly tested in salt spray is shown in Figure 15, illustrating the installed cable. Cable structure is shown in Figure 7.

4.4 Tooling

4.4.1 Cleaving and stripping tooling

4.4.1.1 The present G & H fiber cleaving tool consistently provides an end face with a mirror finish, perpendicular to the fiber axis within $\pm 1^\circ$. Table I shows data for 30 typical cleaves made with the G & H tool. The fiber cleaving mechanism is shown in Figure 14 along with a photograph of a typically cleaved 140 micron Galite 5050ST semi-graded index fiber. A modified tool with an improved lead-in feature and improvements for ease of handling was completed and used in set up for testing. However, at the time of testing, the cleaving was performed with the tool out of adjustment resulting in cleaves of up to 2.5° out of perpendicularity.

Also at the time of testing, a scribe and bend cleaving tool from Fujikura was implemented to evaluate suitability in comparison to the G & H cleaving tool. The Fujikura tool was easy to handle, but examination under the microscope showed more hackle (jagged edges) which sometimes spiked into the core area, and less consistency in end-face perpendicularity to the fiber axis than cleaves made with the G & H tool. The Fujikura tool also "wore out" after about 100 cleaves, no longer cleaving the fiber but making a rough, broken fiber end.

4.4.1.2 Stripping tooling currently used is the conventional wire stripping type with graduated hole sizes implemented for stripping varying diameters of jacketing. The plier type tool is clamped on the fiber, then with a sliding or wiping motion, the jacketing is scraped off the fiber. This method was employed in preparing cable and fiber for contact installation (See 3.4.1). G & H is developing new, unique tooling to avoid the breaking of fibers which occurs using these conventional stripping tools. Chemical strippers have been considered but this is not desirable for field use and consequently not being pursued at this time.

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FIGURE 13

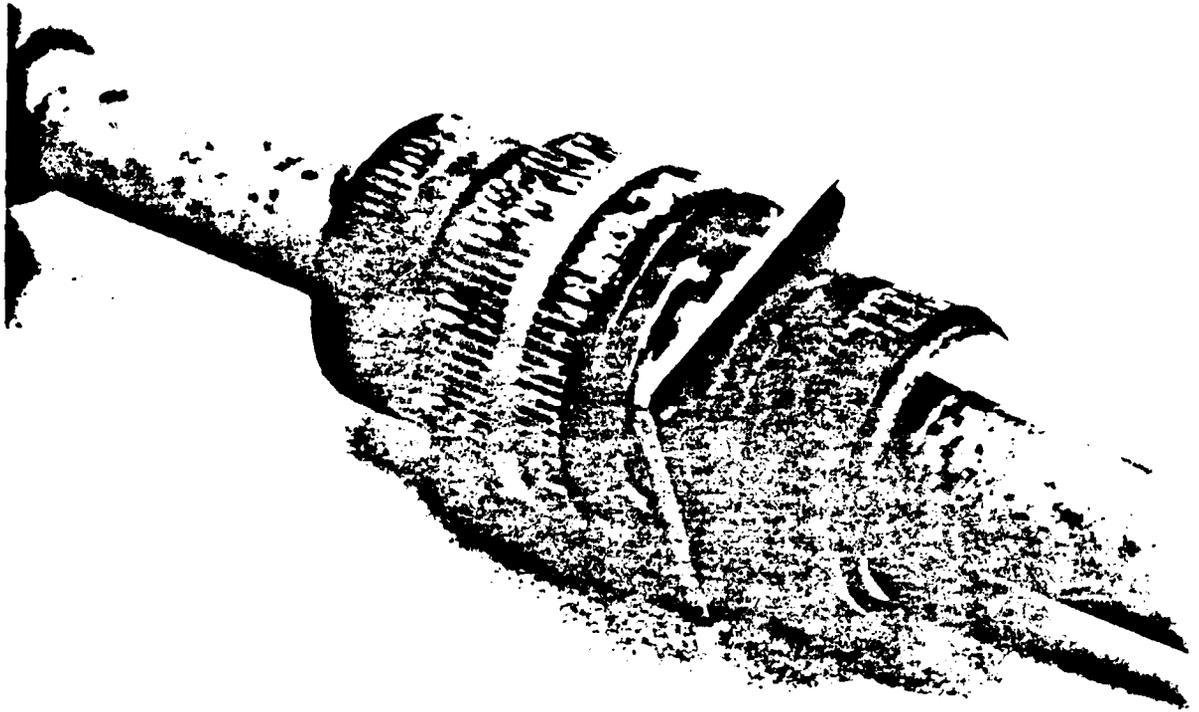
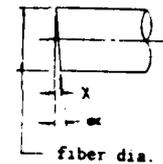


TABLE I

FIBER ENDFACE ANGLES
(CLEAVES PRODUCED WITH G&H CLEAVING TOOL)

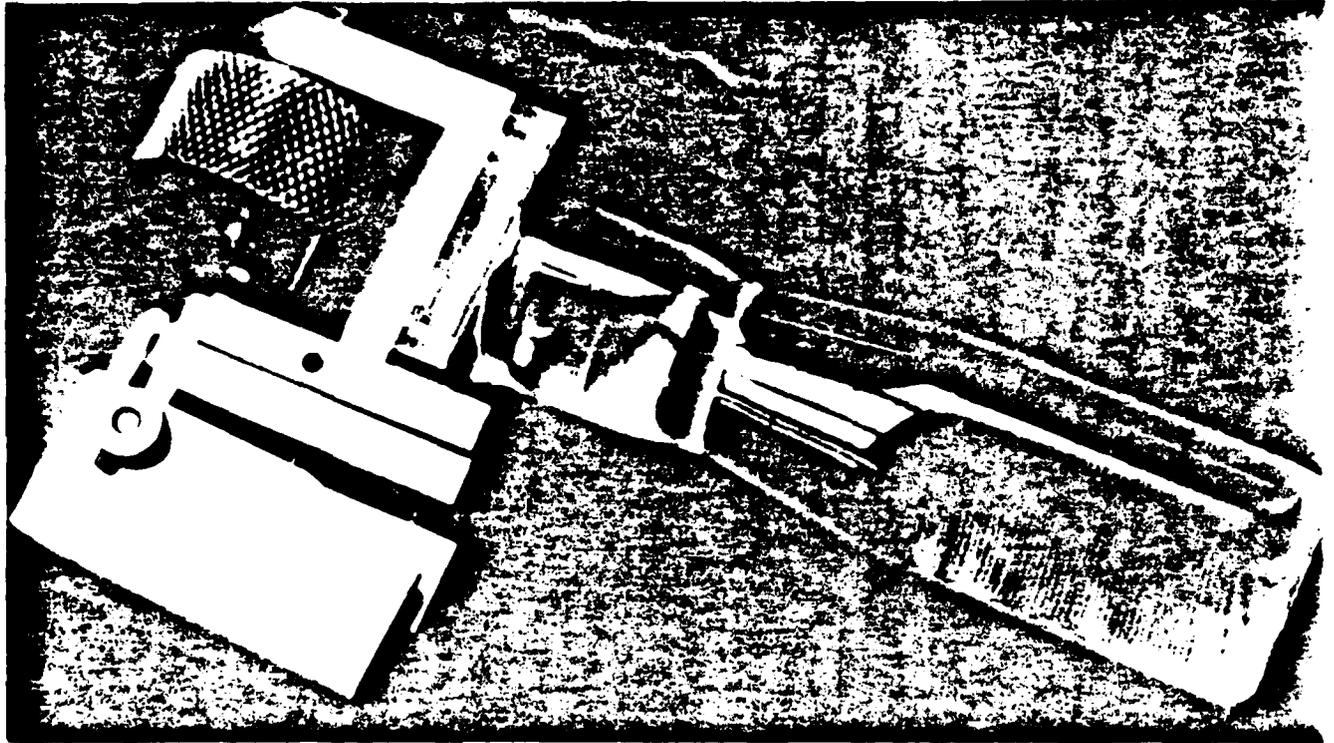
CLEAVE NO.	FIBER DIA. (MICRONS)	"X" DEVIATION FROM PERPENDICULAR	α ANGLE (DEGREES)
1	140	1.0	0.4
2	140	1.0	0.4
3	140	1.0	0.4
4	140	2.0	0.8
5	140	2.0	0.8
6	140	1.0	0.4
7	140	2.0	0.8
8	140	1.0	0.4
9	140	1.0	0.4
10	140	2.0	0.8
11	140	2.0	0.8
12	140	2.0	0.8
13	140	2.0	0.8
14	140	2.0	0.8
15	140	2.0	0.8
16	140	2.0	0.8
17	140	1.2	0.5
18	140	2.0	0.8
19	140	2.0	0.8
20	140	1.0	0.4
21	140	1.0	0.4
22	140	1.0	0.4
23	140	1.0	0.4
24	140	2.0	0.8
25	140	2.0	0.8
26	140	2.0	0.8
27	140	2.0	0.8
28	140	2.0	0.8
29	140	2.0	0.8
30	140	1.2	0.5

$$\alpha = \text{arc tan} \left(\frac{X}{\text{fiber dia.}} \right)$$

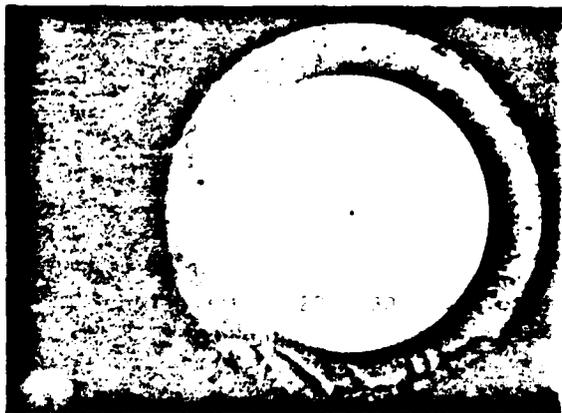


① Galite 5050ST 140 Micron semi-graded index glass fiber

FIGURE 14



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4. Program (Cont'd)

4.4 Tooling (cont'd)

4.4.1.3 The loose tube buffer removal tooling currently used is also the typical wire stripping tooling. The plier type tool is used to clamp the buffer at the point of removal. The tool is removed and the buffer is gripped with the fingers to be pulled off of the end of the fiber. New tooling is being developed for unique, field useable applications on this loose tube buffer. Figure 15 shows all of the stripping and cleaving tools used at present.

4.4.2 Crimping tooling

The G & H three rod fiber optic contact requires crimping of the ferrule on the three precision ground rods. This is accomplished with the tool developed at G & H which holds the three precision ground rods ($\pm .0001$ in diameter) in a cluster and provides the fiber positioning stop to locate the fiber recessed .0001 to .0002 in. relative to the rod ends. The ferrule is then slipped over the exposed rod cluster and crimped with a radial loading on three portions of the rods, lengthwise. The crimped rod sub-assembly is shown in Figure 16. The crimping tool (Figure 17) has been modified to provide more accurate fiber positioning and ease of use.

4.4.3 Assembly tooling

Completing the assembly of the fiber optic contact is accomplished with the bending of 4 tines, incorporated in the body of the contact, over the end cap which will contain the spring loaded ferrule rod sub-assembly in place. A special tool to accomplish this operation has been fabricated at G & H. The tines have previously been bent over using a small probing tool.

4.4.4 Insertion/Removal tooling

The same tools used for insertion and removal of the electrical contacts for the MIL-C-38999 Series IV connector are used for the fiber optic contacts per 3.2.2.

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FIGURE 15

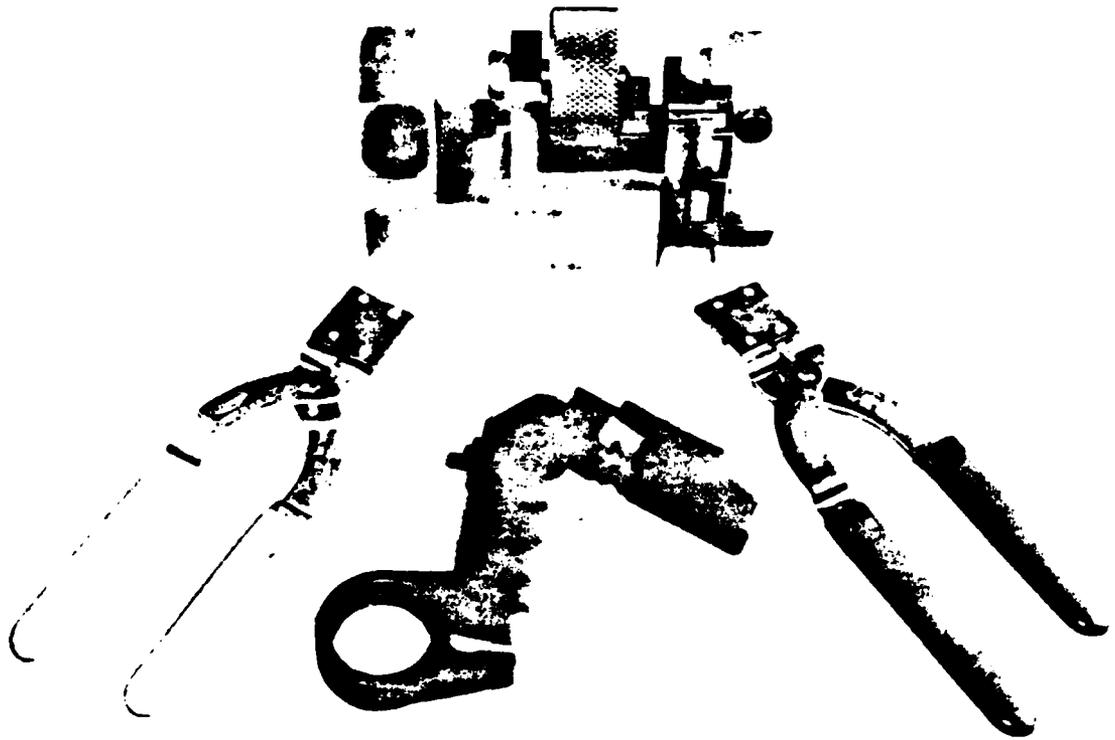
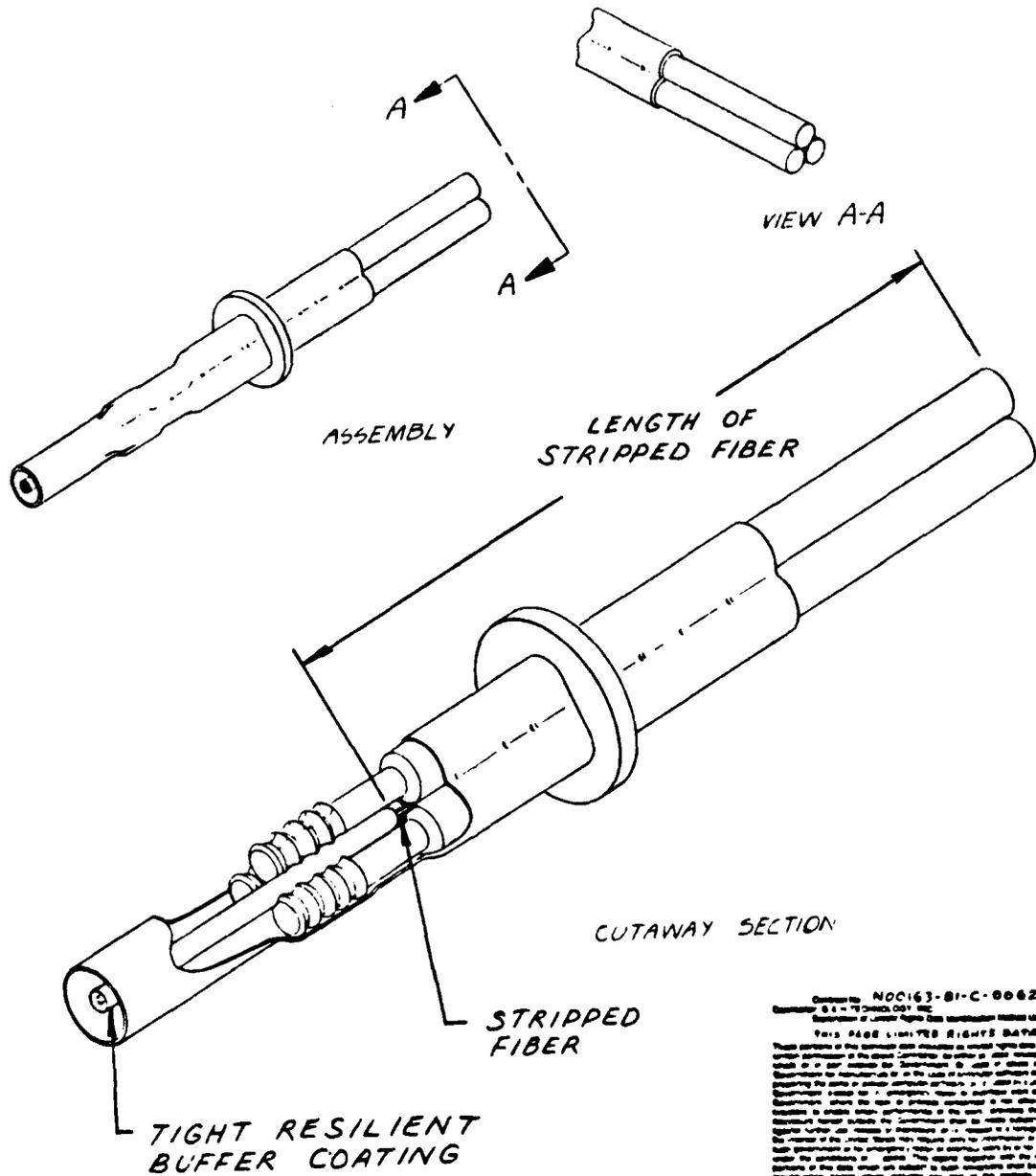


FIGURE 16



Contract: NOC163-B1-C-0062
 Drawings: 61-71-DRAWING ONLY
 Revision: 1 - 10/68
 THIS PAGE LIMITED RIGHTS DATA
 These portions of the technical data described in this report are hereby released to the public in accordance with the provisions of the patent laws of the United States of America, and the rights of the Government in this matter are hereby waived. The release of this information is not intended to constitute an endorsement or approval of the views or opinions expressed hereon, or to be taken as an indication of the standard of workmanship or quality of the work described herein. The release of this information is not intended to constitute an endorsement or approval of the views or opinions expressed hereon, or to be taken as an indication of the standard of workmanship or quality of the work described herein. The release of this information is not intended to constitute an endorsement or approval of the views or opinions expressed hereon, or to be taken as an indication of the standard of workmanship or quality of the work described herein.

4. Program (Cont'd)

4.5 Backshell

4.5.1 The stock backshell obtained for the use with the fiber optic MIL-C-38999 Series IV connectors was used in the environmental connector tests. It was determined that the bore diameter of the backshell was too small to allow passage of all six Galite 5050 ST cables and the small bore was not ideal to provide adequate service loop area for the coiled fibers. The backshell is shown in Figure 18. Three channels were used for tests and the reinforcement member was not confined between the conical mating surfaces as shown in Figure 12. A new custom backshell to specifically accommodate fiber optic cables and hybrid cables is in development.

4.6 Testing program

4.6.1 The scheduled environmental and mechanical connector tests have been conducted on MIL-C-38999 Series IV G & H Breech-lok connectors in thermal shock, humidity, salt spray, vibration, sand and dust, thermal cycling and durability. Results of the tests are presented in Section 4.6.3. Any deviations from the test procedures of Appendix A are described in the text of 4.6.3.

4.6.2 Tests in fluid immersion, cable flexing and cable retention were not conducted because of backshell development not being completed to satisfactorily capture the strength members and seal the cable.

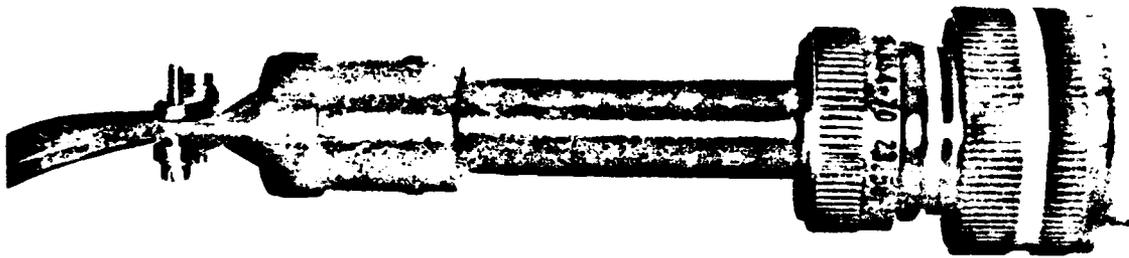
4.6.3 Test results

4.6.3.1 Preparation

4.6.3.1.1 Cable. The cable used in the connector samples assembled for the tests was a combination of Kevlar reinforced Galite 5050 ST cable and fiberglass reinforced Galite Special 5050 ST cable. See 4.6.3.2.1, 4.6.3.4.1, 4.6.3.5.1 and 4.6.3.6.1. The jacketing, loose tube buffer and resilient silastic buffer were removed to the required lengths (see 3.4.1) then the fiber was cleaved ready for contact installation. The strength members were folded back for later use.

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FIGURE 18



4.6 Testing program (Cont'd)

4.6.3 Test results (cont'd)

- 4.6.3.1.2 The G & H cleaving tool was used to prepare fiber ends in cable assembly 1, (used for thermal shock and humidity tests). A scribe, bend and pull hand tool made by Fujikura was used in cable assembly 2 for comparative purposes. Figure 14 shows the G & H cleaving tool. The other test cable assemblies were also prepared with the G & H cleaving tool, as visual examination under the microscope showed more hackle and lesser quality perpendicularity of fiber end faces using the Fujikura tool. (See 4.4.1.1)
- 4.6.3.1.3 Crimping of the ferrule to the three rod cluster was accomplished with the G & H crimp tool per 4.4.2.
- 4.6.3.1.4 Assembly of the contacts was done by hand. The flange which holds the spring in place (Item 15, Figure 6) was soldered into position. The final assembly was then accomplished by use of a small probing tool to bend the tines into place, and later with the G & H assembly tool.
- 4.6.3.1.5 The backshell was installed using the service loop area to lightly coil the stripped silastic buffered fibers. Kevlar and fiberglass reinforcement was clamped with the jacketed cable at the rear of the backshell. Cable ties and wax string windings confined the single cables to a bundle for the 1½-2 meters on each side of the installed connector.
- 4.6.3.1.6 Launching of the source.
A special mandrel providing 1" diameter coils of silastic buffered fiber was used to mode strip each channel in the test set up. The mandrel end also provided a housing for the 880 nm GaAlAs light emitting diode used in each cable assembly. Circuitry for driving the LED at 200 ma was housed with the mandrel in a closed box. Figure 19 shows the mandrel with the LED interface and cable installed.

4.6 Testing program (Cont'd)

4.6.3 Test results

4.6.3.1 Preparation

4.6.3.1.7 Detection methods

4.6.3.1.7.1 Deutsch connectors were used at the ends of the fiber optic cables. The sensor surface with the Photodyne 150 sensor head was selectively signalled to the Photodyne 22XL optical multimeter. Special strain relieving collars were made to induce microbending and microbending losses at the rear of the Deutsch connectors. Figure 20 shows this set up in the test box prepared for this test program. Switching the dial produced immediate digital readings on the optical multimeter. Accurate, repeatable readings were obtained as shown in Table IIA.

4.6.3.1.7.2 The clamping of the cable in the special strain relieving collars induced measureable microbending (lower readings occurred when clamping the standard Galite 5050 ST cable) and because the plugging and unplugging could cause changes in readings with the Deutsch connectors, an alternative method was used to take detector readings in the salt spray test, run simultaneously with the humidity and thermal shock test. An oil bath of Dow Corning 710 fluid was contained in a cylindrical tube mounted over the Photodyne 150 sensor head, and the opening at the top of this approx. 2" long cylinder was a small hole just allowing the silastic buffered fiber to be entered. One fiber at a time was placed in the hole and brought down to the glass slide at the base of the oil bath. Accurate, repeatable readings were obtained as shown in Table IIB. However, it should be noted that this method was "operator technique dependent" so the same person took all the readings indicated in Table IIB.

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FIGURE 20

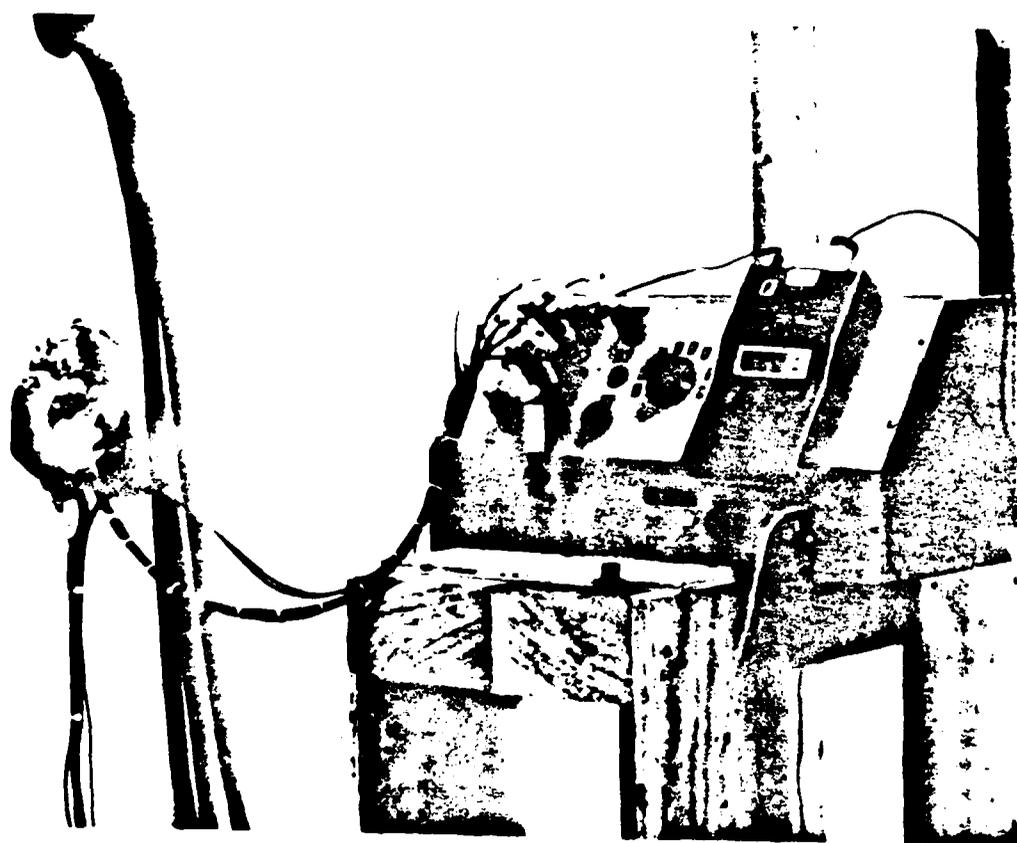


TABLE II

TABLE IIA

CHARACTERIZATION OF CABLE ASSEMBLY NO. 1.
(CABLE ASSEMBLY FOR THERMAL CYCLING, HUMIDITY TESTS)

Channel	Initial Reading (dBμ)	Remove Deutsch Connectors, re-insert		ΔdB Max.
		(dBμ) 11-9-81 1800	(dBμ) 11-10-81 0800	
1	6.0	6.0	6.0	-0
2	5.6	5.6	5.6	+0.1
3	1.6	1.5	2.0	+0.5 [1]
4	-0.7	-0.8	-0.7	-0.1
5	2.6	2.5	2.6	0
6	2.2	2.2	2.5	+0.3 [1]
7	5.7	5.7	5.7	0
8	5.6	5.5	5.6	-0.1

[1] Lines 3, 6 had loose strain relief cable clamps on detector ends, discovered 11-10-81 0800.

TABLE IIB

CHARACTERIZATION OF CABLE ASSEMBLY NO. 2
(CABLE USED FOR SALT SPRAY TEST)

Channel	(dBμ)	(dBμ)	(dBμ)	ΔdB Max.
	11-12-81 1315	11-12-81 1325	11-12-81 1352	
1	5.2	5.4	5.4	0.2
2	3.7	3.8	3.7	0.1
3	6.0	5.9	6.0	0.1
4	6.4	6.4	6.4	0
5	6.5	6.5	6.5	0
6	6.1	6.1	6.1	0
7	3.2	3.4	3.4	0.2
8	6.0	6.0	5.9	0.1

4.6 Testing program (Cont'd)

4.6.3 Test results

4.6.3.1 Preparation

4.6.3.1.8 Insertion loss measurements. See also 4.6.3.9. EIA FOTP-34 "Interconnection Device Total Insertion Loss Test" methods were used.

Each cable assembly was prepared as a bundle of single channel cables held together with tie wraps. Fibers were prepared on one end and fastened to the mandrel and LED and fibers were prepared at the other for the detector method employed. Readings were taken to characterize the cables before they were severed and the connector installed, then again after installation, before testing commenced. Reference lines remained uncut. Loss factors included:

- connector insertion loss. The fiber cleaving techniques or endface condition of the fibers, the alignment of the contacts in the bushing, the end separation of fibers due to the relational position of the fiber and rod ends, all contribute to connector losses.
- backshell clamping. A pair of metal bars were brought together with screws to clamp the cable at the rear of the backshell. This caused some attenuation of signal when the backshell was installed. This effect was much more evident in the standard Galite 5050 ST cable with polyurethane jacketing than in the special Galite 5050 ST cable with Tefzel jacketing.
- cable ties. Following connector installation, cable ties were added to the cable assembly near the connector. These cable ties caused some attenuation when tightened mildly. Again, the effect was more pronounced in the Galite 5050 ST standard cable.
- Fiber diameter uniformity and concentricity of core to cladding will affect insertion loss.

4.6 Testing program (Cont'd)

4.6.3.2 Thermal cycling test. See also 4.6.3.8 "Thermal Shock Test".

4.6.3.2.1 Set Up. The cable assembly used for the thermal cycling had three active channels, lines 1, 4, 5 (connector pin positions A, C and F similar to those shown in Figures 21 and 22) Line 1 was Galite 5050 ST special cable, lines 4 and 5 were standard cable. This cable assembly had three reference lines which were placed in the chamber during testing for observation of effects on the cable. Of these references, line 2 was Galite 5050 ST special cable and lines 3 and 6 were Galite 5050 ST standard cable. Lines 3 and 6 were found to have insufficient strain relief at the detector test box as indicated in Table IIA with significantly non-repeatable readings. There were also two reference lines kept outside the chamber as true comparisons with signal changes in the thermal shock testing. Both lines were Galite 5050 ST standard cable. The mated connector was placed within the thermal shock chamber, lines fed through a 5" port and the port sealed. Detector ends were connected to the test box with the Deutsch connectors and the emitter end was wired to the power supply. This set up remained unmoved for the duration of the thermal cycling test. See Figures 20 and 23.

4.6.3.2.2 Documentation

- A. Thermal Cycling Test, Nov. 11-16, 1981. Set up, K. Korbela, monitoring of optical signal transmission level, W.Lovell, D. Parker.
- B. Sample was a MIL-C-38999 Series IV fiber optic connector with active and reference lines per 4.6.3.2.1.
- C. Equipment was a Tenney Relialab model No. W1-TR-85200 thermal shock chamber with temperature cycling monitored by a Honeywell Servoline 45 chart recorder calibrated 6-17-81. (Typical recorded cycle, Figure 24.)
- D. Test procedure.
The connector was pre-conditioned at room temperature for 24 hours prior to the test. The connector and reference lines were installed in the test chamber and signals were run through the mated connector active channels and reference lines set up per 4.6.3.2.1. The connector was observed and examined following the test. The test was

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FIGURE 21

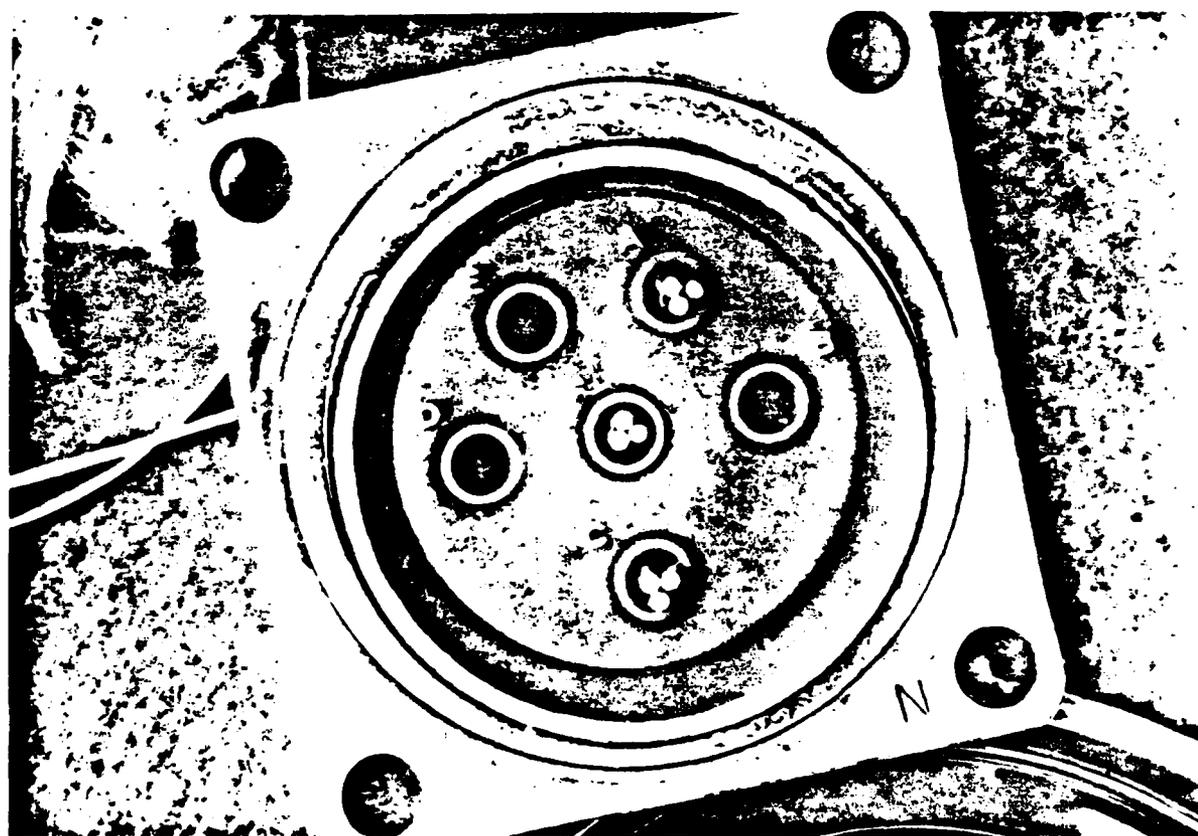
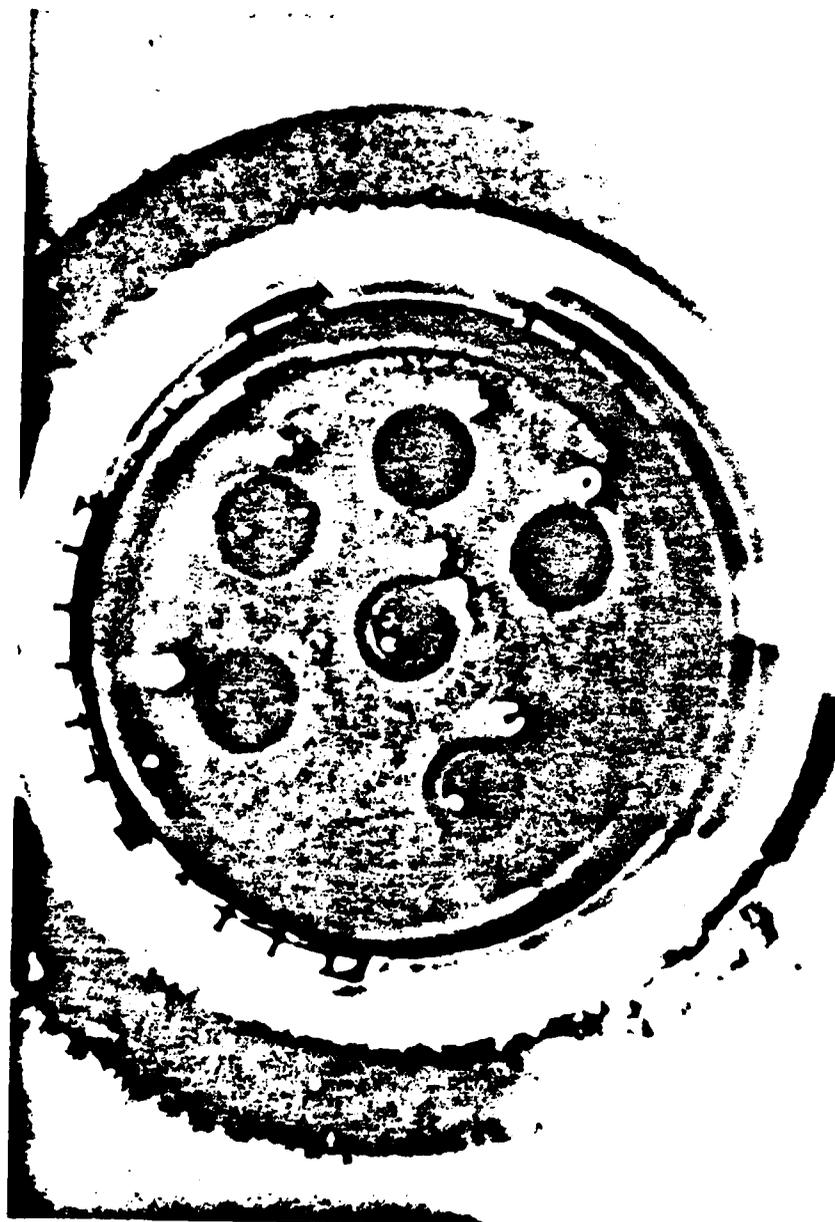
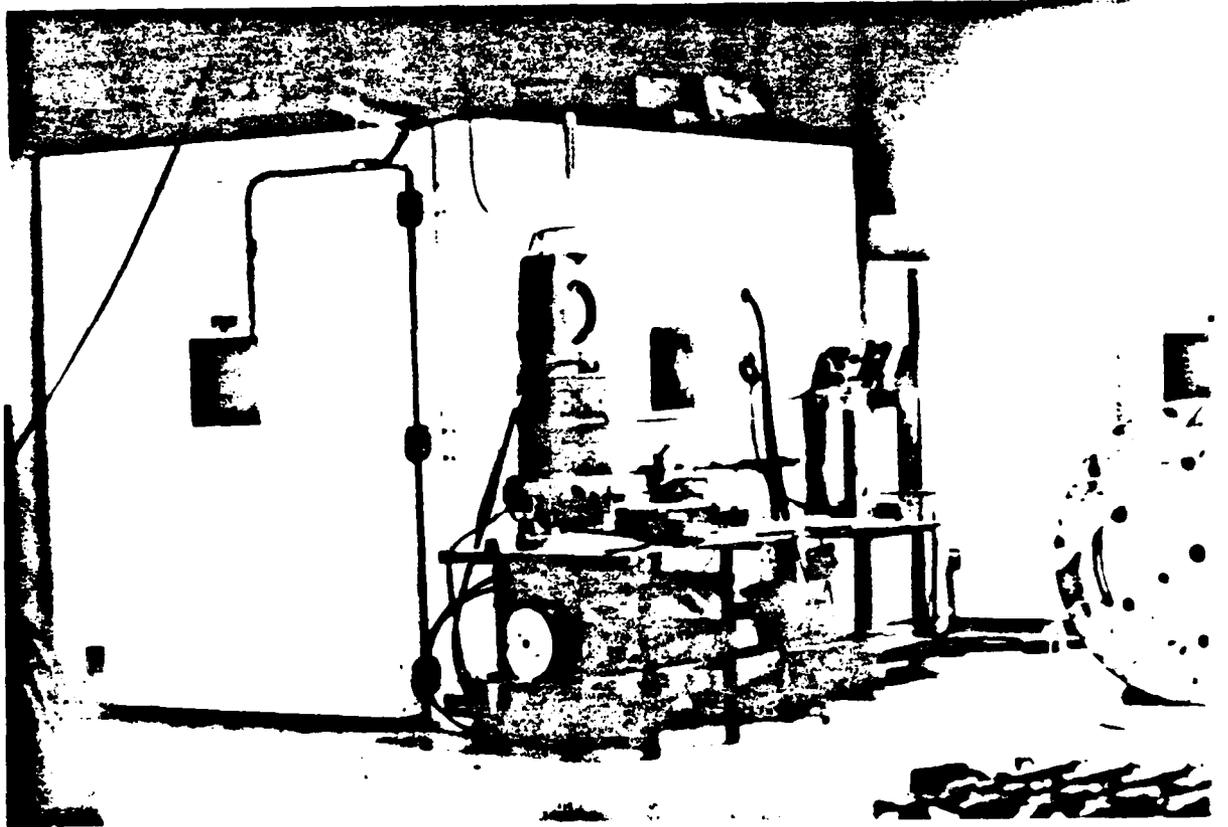


FIGURE 22



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FIGURE 23



4.6.3.2 Thermal Cycling test contd.

4.6.3.2.2 Documentation contd.

run per Thermal Shock Test Procedure of Appendix A with exceptions noted:

Test temperatures were $-35\pm C$ and $+65\pm C$. One chamber was used for both temperature extremes with 9 hour exposure to each extreme and a three hour transition between extremes.

E. Values and Observations

1. Visual examination. Upon completion of the test, examination of the connector and contacts revealed no signs of degradation, change of relative fiber end position, or damage due to the exposure to thermal cycling.
2. Monitoring measurements of the chamber time and temperature was done with a chart recorder per 4.6.3.2.2.C
3. Insertion loss measurements were made per 4.6.3.1.7.1 and per 4.6.3.1.8.
4. The assembly mass was 171.2 grams including backshells.
5. The initial, monitoring and final measurements of attenuation are shown in Table III.

4.6.3.2.3 Conclusions

The test shows that both positive and negative attenuation occurred during high and low temperature cycling. Table III shows the deviation from initial room temperature readings during the course of the test. Lines 1, 4, 5 were active channels installed in the connector. The variations shown can be attributed to several factors. First, the assembly of the contacts is not yet perfected with the crimping tool as used in this test connector. This means the endface position of the fiber relative to the rod ends is not always precisely where it should

TABLE III

THERMAL CYCLING TEST

Channel No.	Actual Readings (Optical Multimeter dBμ)										From Room Temp.	
	11-11 1000 (13°C)	11-11 1100 (22°C)	11-11 1530 (64°C)	11-11 1830 (64°C)	11-12 0900 (-35°C)	11-12 1620 (65°C)	11-12 1830 (65°C)	11-12 0900 (-36°C)	11-12	11-16	dB -35°C	dB 65°C
1	2.3	2.2	2.0	2.0	2.8	2.1	2.1	2.8	2.8	+0.6	-0.2	
2	5.6	5.6	5.5	5.5	5.6	5.6	5.5	5.5	5.5	NC	NC	
3	-1.5	-1.6	-1.9	-1.9	-1.4	-1.7	-1.8	-1.4	-1.4	+0.2	-0.2	
4	-0.1	-0.1	-0.5	-0.6	-1.1	-0.5	-0.5	-0.8	-0.9	-1.0	-0.4	
5	0.6	0.5	0.4	0.5	1.0	0.6	0.6	1.0	1.0	+0.5	NC	
6	2.9	2.9	2.9	2.9	3.0	1	1	1	1	NC	NC	
7	5.2	5.2	5.2	5.2	5.3	5.2	5.2	5.2	5.2	NC	NC	
8	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	NC	NC	

1 Detector sensor head removed for technical reasons

4.6.3.2 Thermal Cycling Test contd.

4.6.3.2.3 Conclusions contd.

be, recessed .0001 or .0002 in. This, plus the expansion and contraction of metallic materials may explain why some readings decreased (butting ends pressed together or ends drawn slightly further apart), and others increased (ends were separated and may have been drawn slightly closer together). Also, the alignment bushing (although molded with a smooth, accurate bore) has not yet been finalized with the optimum i.d. bore. This is currently being finished by the molding vendor. No observable change in relative fiber end position was noted upon final visual inspection.

Deviation of max. and min. temperature levels from the test plan was a result of running the test in conjunction with another test because of scheduling.

Insertion loss results are discussed in 4.6.3.8.

Losses due to cable failure or degradation appear negligible. See also 4.6.3.8 "Thermal shock test."

4.6.3.3 Humidity Test

4.6.3.3.1 Set Up. The cable assembly used for the humidity test had 3 active channels, lines 1, 4, 5. This connector assembly is the same one used in the thermal shock test per 4.6.3.2.1. The connector assembly was pre-conditioned at 50°C for 24 hours. The connector was then set up in a Tenney chamber. Temperature of 40°C was set with a selector dial and monitored with a dry bulb thermometer. Lines 2, 3 and 6 were placed in the chamber during the test for observation of the effects of humidity on the cable. Lines 7 and 8 again were the reference lines coupled to the common 880 nanometer source at one end and to the photodyne 150 sensor heads at the other end. The mated connector was mounted horizontally (Figures 25,26) and "suspended" by laying on a 2" wide plexiglass bridge across a 6" deep vinyl pan. Since the chamber had no controlled

4.6.3.3 Humidity Test Contd..

4.6.3.3.1 Set Up Contd.

humidity setting, a semi-circular plastic hood was placed over the pan (with 2" tap water placed in it) and the whole unit enclosed in a plastic bag. The only opening was the location where the cable assembly emerged from the unit and the bag was wrapped around the cable securely at this location. This arrangement provided humidity and the half-round cover kept the condensation from dripping directly on the connector assembly.

This set up remained untouched during the test with readings taken by selecting the channel with the switching selector knob on the Photodyne optical multimeter (model 22XL) test box.

4.6.3.3.2 Documentation

- A. Humidity test, Nov. 16-19, 1981. Preconditioning operator, D. Parker. Test operator, W. Lovell.
- B. Sample was a MIL-C-38999 Series IV fiber optic connector with active and reference lines per 4.6.3.3.1, fixturing per 4.6.3.3.1 and Figures 25, 26.
- C. Equipment consisted of a Tenney model No. T30C-100350 oven chamber with temperature control setting and a dry bulb thermometer monitor.
- D. Test procedure. The connector was preconditioned at 50°C for 24 hours prior to the test. The connector and reference lines were installed in the test chamber and signals were run through the mated connector active channels and reference lines set up per 4.6.3.3.1. The connector was observed and examined following the test. The test was run per Humidity Test Procedure of Appendix A with exceptions noted:

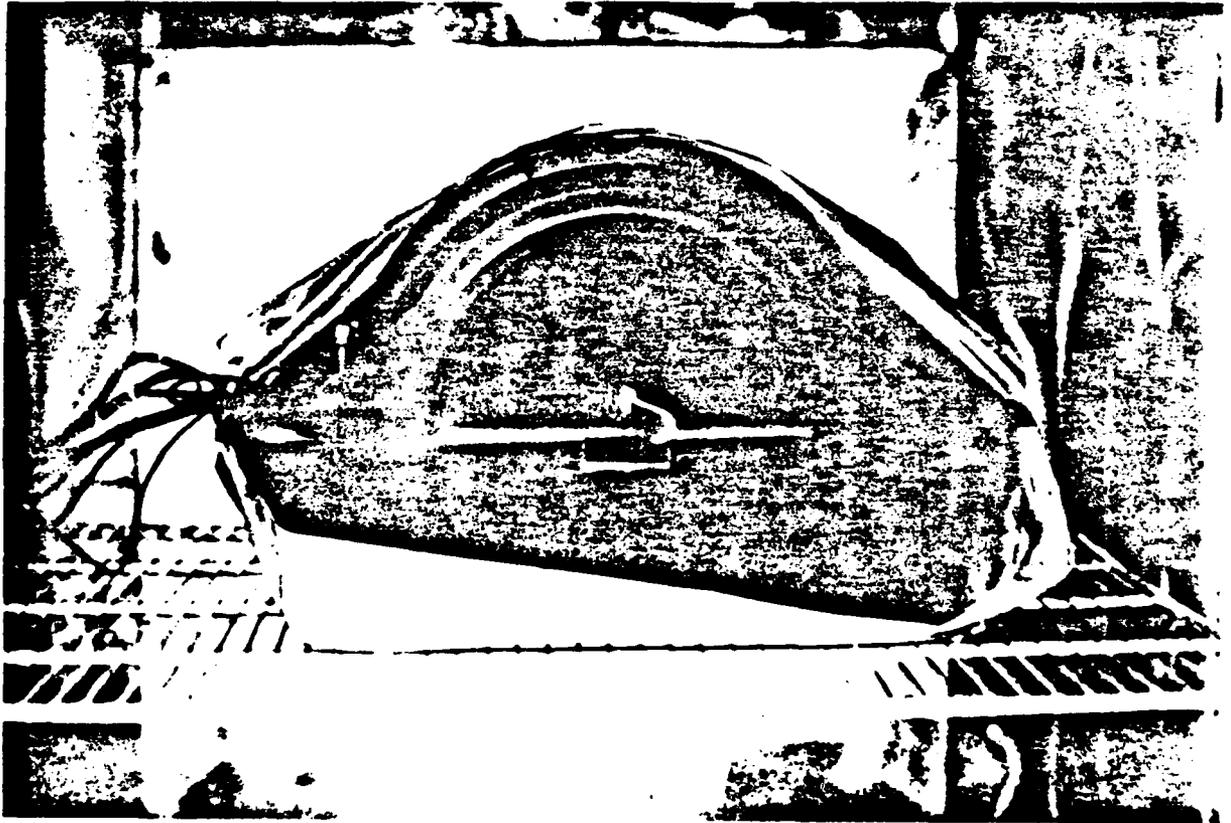
The duration of the test was 48 hours due to scheduling restrictions.

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FIGURE 25



FIGURE 26



4.6.3.3 Humidity Test (contd.)

4.6.3.3.2 Documentation (Contd.)

E. Values and Observations

1. Visual examination. Upon completion of the test, examination of the connector and contacts revealed no signs of degradation or damage due to the exposure to the humidity environment.
2. Monitoring of the chamber temperature was done with visual checking of a dry bulb thermometer.
3. Insertion loss readings were taken by recording individual channel digital optical signals selected by panel switching from the Photodyne 22XL optical multimeter.
4. The assembly mass was 171 grams including backshells.
5. The initial, monitoring and final insertion loss measurements are shown in Table IV.

4.6.3.3.3 Conclusions.

The results in Table IV show that there was attenuation of .1 to .4 dB during the humidity test. This was due to the same influencing factors which affected the readings of the thermal cycle test, listed in 4.6.3.2.3, elevated temperature readings. The active channels were Nos. 1, 4, 5. The reference cables were lines 7 and 8.

Readings are at diminished signal strength levels in lines 4 and 5 because these lines were accidentally severed in removal from the test chamber and then spliced mechanically. Heat shrink tubing was installed over the splices to minimize the vulnerability to damage.

Deviation from the time duration called for in the G & H Test Plan was due to scheduling problems. The actual time was 48 hours instead

TABLE IV

HUMIDITY TEST

Channel No.	Actual Readings (Optical Multimeter dBu)									Loss (dB)
	11-17 1320 (22°C)	11-17 1345 (40°C)	11-17 1700 (40°C)	11-18 0845 (40°C)	11-18 1035 (40°C)	11-18 1400 (40°C)	11-19 0900 (40°C)	11-19 1020 (40°C)	11-19 1420 (40°C)	
1	-5.7	-5.8	-5.5	-5.8	-5.8	-5.8	-5.8	-5.8	-5.8	-0.1
2	5.9	5.7	5.9	5.7	5.7	5.7	5.7	5.7	5.8	-0.1
3	-1.5	-1.7	-1.4	-1.8	-1.8	-1.9	-1.9	-1.8	-1.8	-0.3
4	-2.4	-2.8	-2.5	-2.7	-2.7	-2.8	-2.8	-2.7	-2.7	-0.3
5	1.1	0.9	1.0	0.9	1.0	0.9	0.9	0.9	1.0	-0.1
6	1	1	1	1	1	1	1	1	1	-
7	5.7	5.5	5.7	5.5	5.6	5.5	5.5	5.5	5.5	-0.2
8	5.5	5.5	5.6	5.5	5.5	5.5	5.5	5.5	5.5	0

1 Detector sensor head removed for technical reasons

4.6.3.3 Humidity Test (Contd..)

4.6.3.3.3 Conclusions (Contd.)

of the 96 hours called for in the test plan, Appendix A.

Insertion loss results are discussed in 4.6.3.8.

Losses due to cable failure or degradation appear negligible. (Line 2). Line 6 was eliminated due to removal of the sensor head from the test box for technical reasons.

The housing made for the test provided the required humidity and kept any condensation from dripping on to the tested connector.

4.6.3.4 Salt Spray Test

4.6.3.4.1 Set up. A second cable assembly was characterized and a connector installed for use in the salt spray test. The connector had an environmental, conductive finish per QQ-P-416. There were three active channels, lines 4, 5 and 6 in the connector as shown in Figures 20, 21. Three lines were entered in the chamber to check for cable degradation during testing, lines 1, 2 and 3. Lines 1 and 2 were Galite 5050 ST special cable and line 3 was Galite 5050 ST standard cable. Lines 7 and 8 were reference lines, both Galite 5050 ST standard cable. All lines were coupled at one end to the 880 nanometer common source and wrapped around the 1" diameter mandrel. The other end of the lines were prepared by stripping the jacketing, Kevlar (or fiberglass in the case of the Galite 5050 ST special cable), Hytrel and silastic buffers to expose bare fiber. This fiber was used in the detector set up of 4.6.3.1.7.2 to take light level readings. After connector installation, cable ties were used to confine the several cables to a bundle for ease of handling.

The mated connector was installed in the salt spray chamber, held in a horizontal position by cable ties so that the only part of the connector touching the inert plastic support was one edge of the wall mount flange and one end of one

4.6.3.4 Salt Spray Test Contd.

4.6.3.4.1 Set up Contd.

backshell. The port through which the cables entered the chamber was sealed and the test set set up remained undisturbed during the 96 hours of exposure. Monitoring was done on a bench outside the chamber. The chamber was set up and run per ASTM B117-73, Standard Method of Salt Spray (Fog) Testing.

4.6.3.4.2 Documentation

- A. Salt Spray Test, Nov. 13-17, 1981. Set up J. Esposito, monitoring of optical signal transmission level, W. Lovell, D. Parker.
- B. The sample was a MIL-C-38999 Series IV fiber optic connector, wall mount style with Cad/OD finish per QQ-P-416. Active and reference lines were per 4.6.3.4.1.
- C. Test equipment included the Industrial Filter and Pump Co. Type 411.1 ABC salt spray chamber, and monitoring with Photodyne Model 22XL optical multimeter.
- D. Test Procedure. The connector assembly was tested per Appendix A with the following exceptions:
 - the use of protective waxes was not applied to the wall mount edge touching the inert supporting material.
 - Suspension from the top was not used due to shortage of test cable in the connector assembly.
 - The 48 hours required time was extended to 96 hours.
 - Post drying was done for 18 hours rather than 12 hours due to scheduling.

NOTE: Monitoring was done during the test per Table V. Post cleaning for 5 minutes was done by dipping in running tap water.

5000-82-0078

TABLE V

SALT SPRAY TEST

Channel No.	Actual Readings (Optical Multimeter, dBu)						From Initial Readings ±dB	
	11-13 1140 (22°C)	11-16 1000 (38°C)	11-16 1400 (38°C)	11-17 0900 (38°C)	11-17 1400 (38°C)	Post Cond. (38°C)		11-18 1020 (22°C)
1	5.8	6.1	6.0	6.0	6.1	1	6.0	+0.2
2	4.9	-	1.7	4.3	4.9	1	4.9	-
3	6.1	6.1	6.1	6.1	6.0	1	6.0	-0.1
4	2.9	3.1	3.1	3.1	3.1	1	3.2	+0.3
5	3.2	3.1	3.1	3.0	2.9	1	2.9	-0.3
6	1.8	1.3	1.3	1.2	1.2	1	1.0	-0.8
7	3.6	3.5	3.6	3.6	3.4	1	3.7	+0.1
8	5.9	5.9	5.9	5.9	5.9	1	5.9	-

1 No readings taken during post conditioning

4.6.3.4 Salt Spray Test Contd.

4.6.3.4.2 Documentation Contd.

D. Contd. The connector was examined for degradation of finish and post conditioning was followed by final attenuation measurements.

E. Values and Observations

1. Visual examination showed some signs of backshell finish discoloration.
2. Insertion loss measurements for the cable are discussed in 4.6.3.8.
3. Assembly mass was 171 grams including backshells.
4. The initial, monitoring and final measurements of insertion loss are shown in Table V.

4.6.3.4.3 Conclusions

The test results shown in Table V indicate a change in signal transmission level through the connector after the test was completed. The fact that line 4 had an increase of + 0.3 dB is attributed to the effects of thermal expansion or contraction making the fiber coupling enhance the signal transmission. Inspection showed no visible evidence of moisture penetration of the connector and contact seals to affect the signal transmission. The fiber-optic contact seal is unique to this contact design while the remaining seals are part of the qualified MIL-C-38999 Series IV Connector.

Lines 3, 5 and 6 (active channels) show signal losses of -0.1dB, -0.3dB and -0.8dB respectively due to thermal expansion and contraction and possibly to slight moisture penetration in the chamber, post cleaning or post drying.

4.6.3.5 Sand and Dust Test

4.6.3.5.1 Set Up. The third connector assembly (No. 3) was characterized with uncut cables set up with the launch and detector conditions described in 4.6.3.1.6 and 4.6.3.1.7. The connector was installed and pre-test insertion loss measurements were taken as shown in Table XII, and described in 4.6.3.8.2. The connector had an environmental, conductive finish per QQ-P-416. There were three active channels, contact positions A, B and C. One reference line remained uncut to monitor launch and detector stability providing accurate attenuation measurements. All lines were Galite 5050 ST standard cable. Waxed string was laced around the cables to keep all four lines in a bundle for ease of handling.

The unmated connector was installed in the NTS sand and dust chamber per test procedure of Appendix A and EIA FOTP 35 and tested accordingly. Following the test, dust was gently brushed from the connector and it was lightly tapped on the bench to remove loose particles. New readings were taken with the connector assembled.

4.6.3.5.2 Documentation:

- A. Sand and Dust test, February 11, 1982. Operators J. Juster and G. Malcolm.
- B. Sample was a MIL-C-38999 Series IV 17-6 fiber optic connector, wall mount style with Cad/OD finish per QQ-P-416. Active and reference lines were per 4.6.3.5.1.
- C. Test equipment included an NTS sand and dust chamber, Model No. SD100 meeting the requirements of MIL-C-9436 and a John Fluke digital thermometer, Model No. 2165A-01T.
- D. Test procedure. The connector was tested per Appendix A. After gentle wiping and tapping, final measurements were taken as shown in Table VI.
- E. Values and Observations:
 - 1. Assembly mass was 171 grams including backshells.
 - 2. Initial and final loss measurements for the test conditions are shown in Table VI.
 - 3. Preliminary insertion loss measurements for this cable assembly are shown in Table XII.
 - 4. Fibers were cleaved with the G & H cleave tool.

4.6.3.5.3 Conclusions: Results shown in Table VI indicate there is very little affect on the connector with the exposure to sand and dust. Two channels show virtually no change in signal transmission and one showed a .5 dB loss, possibly due to residual un-wiped dust particles.

TABLE VISAND AND DUST TEST

Channel No.	Connector Position	Initial Reading (dBμ)	Final Reading (dBμ)	Loss (dB)
1	A	4.2	4.2	0
2.	B	5.3	4.8	-0.5
3	C	5.3	5.4	0
4	Ref.	5.5	5.5	0

4.6.3.6 Durability Test

4.6.3.6.1 Set Up. The fourth connector assembly (No. 4) was characterized with uncut cables set up with launch and detector conditions described in 4.6.3.1.6 and 4.6.3.1.7. The connector was installed and pre-test insertion loss measurements were taken as shown in Table XIII and described in 4.6.3.8.2. The connector had an environmental, conductive finish per QQ-P-416. There were three active channels, contact positions B,D and F. One reference line remained uncut providing a monitor of launch and detection conditions. All lines were Galite 5050 ST standard cable. Waxed string was used to confine the cables to a single bundle for ease of handling.

The connector was tested per Appendix A with 500 mate-unmate cycles by hand. Monitoring was done during the test with results as shown in Table VII.

4.6.3.6.2 Documentation:

- A. Durability Test, February 17, 1982. Operator, W. Lovell
- B. Sample was a MIL-C-38999 Series IV 17-6 fiber optic connector wall mount style with Cad/OD finish per QQ-P-416. Active and reference lines were per 4.6.3.6.1.
- C. Test equipment included the optical multimeter monitoring, launching and detection equipment per 4.6.3.1.
- D. Test procedure. The connector was tested per Appendix A with insertion loss measurements taken with each mating for the first 16 matings and unmatings. Thereafter, readings were taken at each 50 matings and unmatings. Results are shown in Table VII.
- E. Values and Observations:
 - 1. Assembly mass was 171 grams including backshells.
 - 2. Initial, monitored and final loss measurements for the test period are shown in Table VII.
 - 3. Preliminary insertion loss measurements for this cable assembly are shown in Table XIII.
 - 4. Fibers were cleaved with the G & H cleave tool.

4.6.3.6.3 Conclusions:

The tabulated results show repeatability of the signal transmission level with variation of 0.2 to 0.4 dB over the 500 mating/unmating cycles. (Loss maximum, -0.2 dB).

TABLE VII

		<u>DURABILITY</u>													
Channel No.	Connector Position	Actual Readings (dBu)													Final Δ dB 1
		Cycle No.													
		1	2	3	4	5	6	7	8	9	10	11	12	13	
1	B	5.0	5.0	5.0	5.0	5.1	4.9	5.0	5.1	5.1	5.0	5.0	5.0	5.1	
2	D	4.6	4.6	4.5	4.6	4.6	4.5	4.5	4.5	4.4	4.6	4.5	4.5	4.5	
3	F	4.8	4.8	4.9	4.9	4.9	4.9	4.8	4.9	4.9	5.0	4.9	4.9	4.9	
4	Ref.	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	

Channel No.	Connector Position	Actual Readings (dBu)														Final Δ dB 1
		Cycle No.														
		14	15	16	50	100	150	200	250	300	350	400	450	500		
1	B	4.9	5.1	5.1	5.0	5.0	5.0	4.8	5.2	4.8	4.7	4.8	4.9	4.8	0	
2	D	4.6	4.5	4.5	4.6	4.7	4.8	4.7	4.8	4.7	4.8	4.8	4.9	4.8	0.2	
3	F	4.9	4.9	4.9	4.9	5.0	5.0	4.9	4.9	5.0	5.0	4.9	5.0	5.0	0.2	
4	Ref.	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.1	5.0	5.0	5.0	5.0	5.0	-	

1 Corrected for reference shift

4.6.3.7 Vibration Test

4.6.3.7.1 Set up. The fourth connector assembly (No. 4) was used for the vibration test following the durability test on that connector assembly. Launch and detector conditions were per 4.6.3.1.6 and 4.6.3.1.7. The connector was installed per 4.6.3.6.1. A special plate machined to accept the wall-mount receptacle was used to mount the mated connector assembly to the vibration cube fixture which was then attached to the vibration machine. Monitoring was done during the testing with the test box set up of 4.6.3.1. Active channels, reference, bundle cabling, connector finish per 4.6.3.6.1.

The connector was tested per Appendix A with exceptions noted in 4.6.3.7.2.

4.6.3.7.2 Documentation

- A. Vibration test, February 18, 1982. Operators W. Lovell, T. Amundsen.
- B. Sample was per 4.6.3.5.2.
- C. Test equipment included shaker assembly Model No. TA 145-150IAR and Hewlett Packard control HP5154C QA analyzer plus monitoring equipment per 4.6.3.1.
- D. Test procedure. The connector assembly was tested per Appendix A with the following exceptions:
 - Random vibration, 0 to 40 G level only was run. The duration of the test was 4 hours in the vertical axis and 2½ hours in a horizontal axis.
 - The area of the backshell where the cables were clamped was taped to simulate the clamping effect of the custom backshell to be later used with this connector.
- E. Values and Observations:
 - 1. Assembly mass was 175 grams including backshells
 - 2. Initial, monitored and final readings of signal transmission are shown in Table VIII.
 - 3. Insertion loss figures for this cable assembly are shown in Table XIII.
 - 4. Fibers were cleaved with the G & H cleave tool.
 - 5. Visual examination showed fiber end position unchanged after the test.

TABLE VIII

VIBRATION														
Channel No.	Connector Position	Actual Readings, Vertical Mode (dBμ)												Loss (dB)
		0940	0942	0943	0944	0948	0950	1000	1005	1010	1330	1337	1340	
1	B	5.0	5.0	5.0	4.9	5.0	5.0	5.0	4.9	4.9	4.7	4.6	4.7	0.4
2	D	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	0.1
3	F	5.0	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.7	4.6	4.6	0.4
4	Ref	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0

Channel No.	Connector Position	Actual Readings, Horizontal Mode (dBμ)												Loss (dB)
		1403	1407	1415	1445	1500	1515	1530	1545	1600	1615	1625 (End)	1625 (Final)	
1	B	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	0.2
2	D	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	0.1
3	F	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	0.5
4	Ref	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0

4.6.3.7 Vibration Test (Cont'd)

4.6.3.7.3 Conclusions:

Results indicate vibration affects are minor for the duration period of this test. Variations in the vertical axis ranged from 0.1 dB (line 2) to 0.3 dB (lines 1 and 3). Variations in the horizontal axis ranged from .05 dB (lines 2 and 3) to .1 dB (line 1).

4.6.3.8 Thermal shock test

- 4.6.3.8.1 Set Up. The third connector assembly (No. 3) was used for the sand and dust test, carefully cleaned and used for the thermal shock test. The connector was per 4.6.3.5.1 and attenuation measurements are shown in Table IX.

The mated connector was tested using two thermal shock chambers per test procedure, Appendix A as noted (Ref. EIA FOTP-3)

4.6.3.8.2 Documentation:

- A. Thermal shock test, February 19, 1982. Operator, W. Lovell
- B. Sample was a MIL-C-38999 Series IV 17-6 fiber optic connector wall-mount style with Cad/OD finish per QQ-P-416. Active and reference lines were per 4.6.3.5.1.
- C. Test equipment included two Tenney thermal shock chambers and monitoring equipment per 4.6.3.1.
- D. Test procedure. The mated connector assembly was monitored for signal level at room temperature, then entered through a port into the cold (-55°C) chamber. A reading was taken 40 minutes later, than at 1 hour, the connector assembly was transported to the hot (+85°C) chamber and a reading taken following entry. This process was continued for 6 hours with readings per Table IX. This procedure conforms to EIA FOTP-3 with the exception of reduction of the number of cycles from 5 cycles to 3 cycles.
- E. Values and Observations:
Degradations during the test were 0.0 to -0.5 dB with losses as shown in Table IX. Variations may have been due to component shrinkage and expansion during cycling, probably influenced by the alignment bushing response. Fiber end position remained unchanged after the test, confirmed by visual inspection.

TABLE IX

THERMAL SHOCK TEST

Channel No.	Actual Readings (dBu)												Change From Room Temp		
	1000 20°C	1040 -55°C	1100 85°C	1200 -55°C	1240 -55°C	1250 -55°C	1300 +85°C	1340 +85°C	1400 -55°C	1440 -55°C	1500 +85°C	1600 +85°C	dB (-55°C)	dB (+85°C)	
1	2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	-0.2	-0.2
2	2	5.2	5.2	5.3	4.9	5.3	5.3	5.3	4.9	4.9	5.3	5.3	4.8	-0.3	-0.4
3	2	5.7	6.0	5.9	5.3	5.7	5.6	5.7	5.3	5.3	5.5	5.5	5.3	-0.4	-0.4
4	1	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	-	-

1 Reference line

2 Active Channels

TABLE X

RELATIVE RESPONSE TO SHIFT OF REFERENCE LEVEL
(INCIDENT SOURCE)

Channel	Shift (dBu)											
	Channel 8 ¹						Channel 7 ²					
	-0.2	0	0.2	0.4	0.6	0.8	-0.2	0	0.2	0.4	0.6	0.8
1	5.8	6.0	6.2	6.4	6.6	6.8	5.9	6.0	6.2	6.4	6.6	6.8
2	5.4	5.6	5.8	6.0	6.2	6.4	5.4	5.6	5.8	6.0	6.2	6.4
3	1.7	1.9	2.1	2.3	2.5	2.7	1.7	1.9	2.1	2.3	2.5	2.7
4	-0.8	-0.7	-0.5	-0.3	-0.1	0.1	-0.9	-0.7	-0.4	-0.3	-0.1	0.1
5	2.4	2.6	2.8	3.0	3.1	3.4	2.4	2.6	2.8	3.0	3.2	3.4
6	2.2	2.4	2.7	2.8	3.0	3.2	2.3	2.4	2.6	2.8	3.0	3.2
7 Ref.	5.5	5.7	5.9	6.1	6.3	6.5	5.5	5.7	5.9	6.1	6.3	6.5
8 Ref.	5.4	5.6	5.8	6.0	6.2	6.4	5.4	5.6	5.7	6.0	6.2	6.3

¹ Channel 8 was adjusted through gradually increasing the 880 nm signal by 0.20 dBu increments.

² Channel 7 was adjusted through gradually increasing the 880 nm signal by 0.20 dBu increments.

4.6.3.8 Thermal shock test (cont'd)

4.6.3.8.3 Conclusions:

The test shows deviations occurring to a lesser extent than the results of the first thermal shock test. This indicates a definite improvement in the stability of alignment because of the lower value of deviations and especially because the temperature ranges were higher on the hot side (+85°C instead of +65°C) and lower on the cold side (-55°C instead of 35°C). In addition, the transition from the hot temperature to cold and vice versa was in an immediate change from one chamber to the next, whereas in the prior test, the transition was gradual over 3 hours. The improvement was anticipated as the alignment member had an inside diameter dimension change made per 4.1.1.

4.6.3.9 Insertion Loss

4.6.3.9.1 Procedure, EIA FOTP-34 was followed. The procedure of preparing the launch conditions for each cable assembly is per 4.6.3.1.6. Detection methods are found in 4.6.3.1.7.1 for connector assemblies 1, 3 and 4 and in 4.6.3.1.7.2 for connector assembly 2. Insertion loss methods are discussed in 4.6.3.1.8 and specific set up information is reported for each test in the appropriate paragraph.

4.6.3.9.2 Results of insertion loss are shown in Tables XI, XII, XIII, and XIV.

Table XI shows the losses of the connector assembly used for the thermal shock and humidity tests. Thermal shock was run first. The effect of tightening the backshell clamp on the cable assembly is shown with the losses increasing with increased clamping. The relatively high insertion loss factors are due primarily to the stage of development of the assembly techniques, cleave tool, and the fiber locating and contact crimp tooling in November, 1981, at the time of this connector installation. Lines 1, 4 and 5 were the active channels showing insertion loss. All three were degraded in the .4 to .7 dB range of signal transmission by increasing the cable clamping.

TABLE XI

INSERTION LOSS, CABLE ASSEMBLY NO. 1
(CONNECTOR ASSEMBLY FOR THERMAL SHOCK, HUMIDITY TESTS)

Channel	Cable Type	Uncut Reading (dBμ)	Loose Backshell Clamp		Snug Backshell Clamp		Tight Backshell Clamp	
			(dBμ)	Loss (dB)	(dBμ)	Loss (dB)	(dBμ)	Loss (dB)
1	140 Micron Fiberglass	6.0	2.5	-3.6	2.2	-3.8	1.8	-4.2
2	140 Micron Fiberglass	5.6	5.6	0	5.6	0	5.6	0
3	140 Micron Kevlar	1.9	1	1	1	1	1	1
4	140 Micron Kevlar	-0.7	-3.3	-2.5	-3.1	-2.4	-3.5	-2.8
5	140 Micron Kevlar	2.6	1.0	-1.6	0.8	-1.9	0.4	-2.2
6	140 Micron Kevlar	2.4	2.9	0.4 2	2.9	0.4 2	2.9	0.4 2
7	140 Micron Kevlar	5.7	5.7	0	5.7	0	5.7	0
8	140 Micron Kevlar	5.6	5.6	0	5.6	0	5.6	0

1 No readings taken as this line was uncut before testing began.

2 Disturbance of detector end may have caused this positive change. The detector strain relief was noted to be loose after connector installation.

TABLE XII

INSERTION LOSS, CONNECTOR ASSEMBLY NO. 2
(CONNECTOR ASSEMBLY FOR SALT SPRAY TEST)

Channel	Connector Position	Cable Type	Uncut Reading (dBμ)	Reading, Connector Installed (dBμ)	Insertion Loss (dB)
1		140 Micron Fiberglass	5.4	5.8	+ .4 [2]
2		140 Micron Fiberglass	3.7	4.9	+1.2 [2]
3		140 Micron Kevlar	6.0	6.1	+ .1 [2]
4	A	140 Micron Kevlar	6.4	2.9	-3.5 [1]
5	C	140 Micron Kevlar	6.5	3.2	-3.3 [1]
6	F	140 Micron Kevlar	6.1	1.8	-4.3 [1]
7		140 Micron Kevlar	3.4	3.6	+ .2 [3]
8		140 Micron Kevlar	5.9	5.9	- [3]

- [1] Active channels
 [2] Uncut cables in the chamber during testing
 [3] Reference lines, outside the chamber

TABLE XIII

INSERTION LOSS, CONNECTOR ASSEMBLY NO. 3

(CONNECTOR ASSEMBLY FOR SAND AND DUST TEST)

Channel	Connector Position	Cable Type	Uncut Reading (dBμ)	³ Reading, Connector Installed (dBμ)	Insertion Loss (dB)	Reading Contacts Rotated to Optimum (dBμ)	Insertion Loss, Optimum (dB)
1	A	140 Micron Kevlar	5.5	3.6	-1.9	4.2	-1.3 ²
2	B	140 Micron kevlar	7.2	3.6	-3.6	5.4	-1.8 ²
3	C	140 Micron Kevlar	7.0	4.9	-2.1	5.3	-1.7 ²
4		140 Micron Kevlar	5.5	5.5	¹	¹	¹

¹ Uncut reference had no change in reading² "Optimum" position obtained by rotating the contacts to the highest reading point³ After connector assembly and backshell clamp

TABLE XIV

INSERTION LOSS, CONNECTOR ASSEMBLY NO. 4
(CONNECTOR ASSEMBLY FOR DURABILITY, VIBRATION TESTS)

Channel	Connector Position	Cable Type	Uncut Reading (dB μ)	² Reading, Connector Installed (dB μ)	Insertion Loss (dB)
1	B	140 Micron Kevlar	6.5	5.3	-1.2
2	D	140 Micron Kevlar	6.4	4.7	-1.7
3	F	140 Micron Kevlar	6.5	4.5	-2.0
4		140 Micron Kevlar	5.0	¹	¹

¹ Uncut reference had no change in reading

² After connector assembly and backshell clamp

4.6.3.9 Insertion Loss (Cont'd)

4.6.3.9.2 Results of Insertion Loss are Shown in Tables XI, XII, XIII, and XIV (cont'd)

Table XII shows the losses of the connector assembly used for the salt spray test. Again, the high insertion loss of the active channels was largely due to the state of the art of tool development, experience and working conditions at the time of this assembly in November, 1981. A Japanese hand tool, Fujikura Ltd., was used for these cleaves. The cleaves were not of the quality of the G & H tool cleaves. End finish was of poorer quality with more hackle and greater angular deviation from perpendicularity to the fiber axis (see 4.4.1.1). Readings for the lines which were placed in the chamber along with the connector "improved", especially line 2. This was likely the result of a straightened bend in the cable after installation in the chamber.

Table XIII records the insertion loss measurement obtained in the installation of cable assembly No. 3 used for the sand and dust test and the thermal shock test. Insertion loss readings have become noticeably improved with the implementation of the most recent G & H cleave tool. Also assembly techniques have improved to decrease the time for assemblies and to better the relative position of the fiber and rod ends. Examination showed, however, in the case of line 2, one rod protruded slightly beyond the others on one side, and one rod was slightly recessed on the other side creating a significant variation in readings upon rotation of the contacts. This points again to the demand for precise end positioning of the rods and fiber. Concentricity of the fiber core to cladding will also affect the signal transmission with rotation of contacts.

Table XIV indicates the insertion loss measurements for the connector assembly used in the durability and vibration tests. (Durability was run first). As experience is gained and the tooling is improved, the signal transmission shows correspondingly lower losses.

5.0 SUMMARY, CONCLUSIONS

5.1 General

The objectives of producing a working fiber optic connector and associated assembly and preparation tooling have been met. Areas of further improvement are backshell development, improvement of assembly techniques, development of cable to contact strain relief and overall streamlining of the fiber optic contact system.

5.2 Discussion of Losses

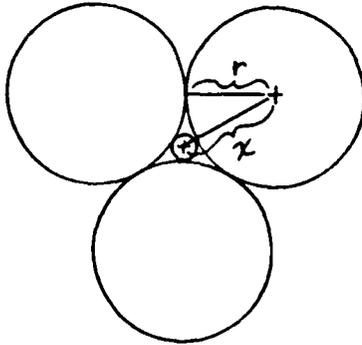
5.2.1 Theoretical rod and fiber tolerances.

The rods which align each fiber in the contacts have a tolerance range of .0002 in. Inspection shows these dimensions are held. The fiber has a published tolerance of $\pm 1\%$ of the cladding OD which is ± 1.4 micron or a range of .0001 in. OD variation. The manufacturer claims realistically $\pm 3\%$ which is ± 4.2 micron or a range of .0003 in. OD variation. Some fiber was actually out of tolerance by 5-6%. Assuming 3% variation can be held, the worst case of axial mismatch would be the maximum material condition of the rods with minimum material condition with the fibers. This would occur if all three rods had OD measuring .0362 in. and the fibers had OD measuring 135.8 micron and were offset from the central alignment bushing axis in opposite positions. Fig. 3B shows that the offset would add approximately 0.3 dB attenuation to the transmission of original signal. Figure 27 shows the calculations. Added to this would be any core/cladding concentricity variation.

5.2.2 Other theoretical losses

5.2.2.1 Fresnel loss. This is loss due to the reflection at each face or approximately .34 dB for a core index of refraction of 1.49 for Galite 5050ST cable. Typical loss due to angular misalignment of step index glass fibers is shown in Figure 3. Semi-graded index Galite 5050ST fiber behaves similarly. If both fiber ends have a cleave with an angle of up to 1° away from perpendicularity to the fiber axis, Figure 3 shows approximately .25 dB loss for 2 fibers with 1° angular misalignment. Loss due to an end separation of .0003 in. is .25dB. For a gap of .0005, loss is .35 dB (Figure 3A). It is clear that with the addition of all the listed loss factors plus other factors such as cable/fiber diameter inconsistencies, numerical aperture mismatch, the fiber construction, cleaving and connecting losses can easily exceed 1 dB.

FIGURE 27



$$\begin{aligned}
 d_{\text{interstice}} &= 2(x - r_{\text{rod}}) \\
 &= 2\left(\frac{2r_{\text{rod}}}{\sqrt{3}} - r_{\text{rod}}\right) \\
 &= 2r_{\text{rod}}\left(\frac{2}{\sqrt{3}} - 1\right)
 \end{aligned}$$

$$\begin{aligned}
 \frac{r}{\sqrt{3}} &= \frac{x}{2} \\
 \therefore x &= \frac{2r}{\sqrt{3}}
 \end{aligned}$$

$$\begin{aligned}
 d_{\text{interstice max}} &= 2r_{\text{max}}\left(\frac{2}{\sqrt{3}} - 1\right) \\
 &= d_{\text{rod, max}}\left(\frac{2}{\sqrt{3}} - 1\right) \\
 &= (.0362)\left(\frac{2}{\sqrt{3}} - 1\right) \\
 &= 142.24 \text{ micron}
 \end{aligned}$$

$$\begin{aligned}
 d_{\text{interstice min}} &= d_{\text{rod, min}}\left(\frac{2}{\sqrt{3}} - 1\right) \\
 &= (.0360)\left(\frac{2}{\sqrt{3}} - 1\right) \\
 &= 141.45 \text{ micron}
 \end{aligned}$$

Min. fiber dia. = 135.8 micron (-3% of 140 micron)

Worst condition: 142.2 - 135.8 = 6.4 micron

From Figure 3B, L = 6.4, D_c = 135.8 $\frac{L}{D_c} = .047 \approx .05$

$$\text{dB}_{\text{loss}} = -0.3$$

5.0 SUMMARY, CONCLUSIONS CONT'D

5.2 Discussion of Losses Cont'd.

5.2.3 Measured insertion losses.

Tables XI, XII, XIII, and XIV show the effects of improved techniques and the use of improved tooling on the signal transmission through the connector. Early assemblies were done under poor conditions with tooling not yet refined to the point of tooling used on the last assemblies of early 1982. The alignment bushings have gone through a series of improvements with additional changes yet planned for better contact alignment. The critical fiber and rod end positioning tooling has undergone changes and is in current process of improvement. Some losses were induced by the backshell clamping. A new backshell will provide less sharp clamping and utilize the strain relief members more efficiently.

5.3 Testing Results

The series of tests run show the practicality of the contact design.

5.3.1 Discussion of results.

Results of thermal shock, humidity and salt spray tests show the connector concept is functional. Especially encouraging are the vibration, durability and sand and dust tests which resulted in low transmission losses. The vibration test was run to the full random G levels which are required to qualify the MIL-C-38999 Series IV connector with losses well below 0.5 dB. 500 mate and unmate cycles resulted in losses of 0.4 dB max. In sand and dust, one channel showed a loss of 0.6 dB when examined following the test per Appendix A procedure requirements. When carefully cleaned after this, the losses decreased to less than 0.1 dB. Field cleanliness is of primary concern. Humidity testing showed losses of 0.3 dB max. Thermal shock results showed "improvements" with cold temperature and losses of 0.4 dB max. at elevated temperatures.

5.3.2 Deviations

The test plan submitted earlier included some tests (which require a fully developed backshell) cable retention and cable flexing. These tests were not required by contract and could be run when a newly designed backshell is produced.

The molded alignment bushings used at the time of the humidity, thermal cycling and salt spray tests were made of Ryton. These were improved upon by decreasing the ID with polishing of the core and molding Valox 430 SEO bushings for the vibration, sand and dust, durability, and thermal shock tests.

5.0 SUMMARY, CONCLUSIONS CONT'D

5.3 Testing Results Cont'd

5.3.2 Deviations Cont'd

The thermal shock test was run using the temperature range called for in the test procedures of Appendix A with results following the same trends as the thermal cycling test.

5.4 Termination Process and Applicability

5.4.1 The procedure involved in terminating each fiber with the optical contact was developed prior to and improved upon during the contract period. Complete termination of each contact involves cable stripping, fiber cleaving, crimp installation of the fiber aligning rod assembly and crimping of the contact body to complete the spring loaded contact. The process can be accomplished with existing tooling, although some operations such as the cleaving (done with the G & H cleaving tool) are performed *much more* satisfactorily than others, such as the final contact body crimping process which is still being improved upon. Results in signal transmission completion have improved significantly as the procedures have been streamlined. There is no use of epoxies, index matching fluids or other complex and undesirable operations to complicate field use of this connector. This contact design has been used with both 125 micron and 140 micron glass fibers with tight buffer coatings, but not with metallic-coated fibers.

5.4.2 Use of a suitable backshell is essential to the success of the fiber optic connector. It was recognized that the backshell must provide protection of the fiber/contact area at the rear of the connector as well as strain relief utilizing the Kevlar or fiberglass cable strength members. A stock backshell was used for the testing program. This backshell implemented the basic features required for the MIL-C-38999 Series IV fiber optic connector, but a new backshell with revised proportional dimensions appears to be necessary following the handling and evaluation of the stock backshell in the assembly and testing program. A shorter, larger diameter backshell with a more suitably adapted strain relief capturing feature (more rounded transition radiused edges will maximize the potential tensile properties of the strength members) will improve the usefulness of the fiber optic connector. Also, improvement in the cable clamping area to provide uniform radial loading without sharp point protrusions will aid backshell redesign.

5.0 SUMMARY, CONCLUSIONS CONT'D

5.4 Termination Process and Applicability Cont'd

5.4.3 Of additional concern is the capability to terminate at least a portion of the strength members at the rear of the contact to provide a much more rugged construction and suitability for field use. The present design includes a seal at the rear of the contact to both protect the contact from rear entering contamination and to protect the fiber from breakage at the tail area of the contact. However, the fiber coiled in the backshell service loop still is a fragile part of the connector when the backshell is removed for any field service. Currently, this problem is being addressed in a developmental manner.

5.5 Tooling

5.5.1 Current models of tooling are satisfactory for performing the preparation and contact assembly. Each tool has undergone considerable modification over the contract period to improve performance and ease of handling. It is recognized that additional improvement, especially in the contact assembly crimping tools (which serve to precisely locate the prepared fiber end for optimum signal transmission as well as completing the assembly termination) will be advantageous.

5.5.2 The ultimate goal would be a compact termination kit containing in one box the necessary quick-use tooling for cleaving, crimping, inspection and cleaning required for field termination and repair.

5.6 Recommended Changes and Follow-On Work

5.6.1 As reported, the fiber optic connector as developed is functional, including present installation tooling. There are areas which can be improved upon with additional development.

5.6.1.1 Evaluation of the materials used in component fabrication should be made to optimize the usefulness of the design in areas of strength, cost, reliability and compatibility for assembly.

5.6.1.2 The cleave tool provides excellent results. Modification to facilitate manufacturing and adaptability to field use should be pursued. The crimp tooling requires further development to provide compact, accurate adaptability to field use. It is desirable to develop crimp tooling with a plier type mechanism much more suitable to daily use than the current models.

5.0 SUMMARY, CONCLUSIONS (CONT'D)

5.6.1 Recommended Changes and Follow-On-Work (cont'd)

New tooling such as buffer strippers may be developed. A complete field kit containing all tooling, inspection and cleaning equipment with fixed stations in a tool box is desirable for installation and repair.

5.6.1.3 Additional backshell development will greatly improve the handling and reliability characteristics of this connector. Use of a shorter backshell than the one used in the contract test program (see Figure 18) with a larger barrel diameter for adequate service loop, improved strain relief tie off, and special cable clamping to distribute loading uniformly over a segment of each cable, accommodating various cable diameters, are minimum requirements of additional design.

5.6.1.4 As discussed in 5.4.3, the termination of cable strength members on the contact is desirable. Suggested ways to accomplish this include a ring externally crimped onto the contact rear area capturing the strength members between the ring ID and the contact OD or an internally positioned ring which, under external crimping of the contact rear area, would capture the strength members between the ring OD and contact ID. It is recommended that a cable structure be used such that single channels be jacketed including strength members and that the single channels be jacketed together into one larger cable with additional strength members. This would allow strength member termination at both the contact and the rear of the backshell, necessary for installation/removal integrity of the contacts and unit integrity of the cable/backshell clamping.

5.6.2 Additional directly related work may involve development of contacts for smaller or larger fibers (the current design has been used for 125 and 140 micron glass fibers) for smaller contact sizes and for other types of fibers such as plastic or PCS (plastic clad silica) fibers. Without changing the MIL-C-38999 Series IV connector contact cavity for sizes 16 and 20 contacts, analysis shows the described 3 rod contacts do not lend themselves to size 16 or smaller contacts for 125 micron or larger fibers, since the rod size is determined by the fiber size. Conceptual development is in progress to design a new contact system for these smaller contact sizes such that they will satisfy the criteria of 3.1.

5.0 SUMMARY, CONCLUSIONS (CONT'D)

5.6.2 (cont'd)

Methods of termination in the field may be explored utilizing splicing or other techniques as an alternative to field termination of contacts as discussed with R. Katz. The development of a fiber optic splice utilizing connector termination concepts could produce reliable field terminable mechanical splices and a field kit for termination and repair.

5000-82-0078

APPENDIX A
TEST PROCEDURES

<u>Page</u>	<u>Title</u>
2A	Thermal Shock Test Procedure
6A	Humidity Test Procedure
8A	Salt Spray (Corrosion) Test Procedure
15A	Sand and Dust Test Procedure
17A	EIA FOTP-35
20A	Vibration Test Procedure
29A	Durability Test Procedure

THERMAL SHOCK TEST PROCEDURE (Ref. EIA FOTP-3)

1. INTENT

1.1 The intent of this test is to determine the effect of temperature cycling on the optical and mechanical characteristics of the fiber optic connector. This test procedure is intended to simulate the worst probable conditions of storage, transportation, and application. Effects of thermal shock include cracking and delamination of finishes, opening of thermal seals and case seams, rupturing or cracking of hermetic seals and metal seals and change of optical characteristics due to mechanical displacement or rupture of fibers.

1.2 Typical indications of damage resulting from this test are:

- (A) Inability to unmate or mate
- (B) Broken parts or accessories
- (C) Damage to seals
- (D) Optical degradation through misalignment, etc.

2. TEST EQUIPMENT

2.1 Test Chambers

Separate chambers shall be used for the extreme temperature conditions of steps 1 and 3, Table 1. The air temperature of the two chambers shall be held at each of the extreme temperatures by means of circulation and sufficient hot- or cold- chamber thermal capacity so that the ambient temperature shall reach the specified temperature within 2 minutes after the specimens have been transferred to the appropriate chamber.

3. TEST SAMPLE

3.1 Sample and fixture

A test sample shall consist of a plug, a receptacle, or a mated plug and receptacle as specified. The test sample shall be assembled with contact, fibers and sealing plugs, before, during and after the test. The cable shall be of sufficient continuous length to interconnect the test connector and test equipment.

3.2 Sample Preparation

The test samples shall be preconditioned at room temperature and approximately 50% relative humidity for 24 hours prior to the test.

4. TEST PROCEDURE

The connector assembly operating conditions during the exposure shall be specified.

4.1 Initial and Final Measurements

Specified measurements shall be made prior to the first cycle and upon completion of the final cycle, except that failures shall be based on measurements made after the specimen has returned to thermal stability at room ambient temperature following the final cycle.

4.2 Sample Mass Determination

Before cycling, the combined mass of the assembly (mated, if applicable) to be tested shall be determined. This mass shall include contacts, sealing rings, connector accessories attached to the connector, and fiber within the envelope boundaries of the connector. The mass of the specimen is the total mass of the mated assembly.

4.3 Number of Cycles

Specimens shall be placed in such a position with respect to the airstream that there is substantially no obstruction to the flow of air across and around the specimen. The specimen shall then be subjected

to the specified test condition of Table 1. The five cycles shall run continuously. After five cycles, the specimens shall be allowed to return to room ambient temperature. One cycle consists of steps 1 through 4 of the applicable test condition. Specimens shall not be subjected to forced circulating air while being transferred from one chamber to another. Direct heat conduction to the specimen should be minimized.

TABLE 1
TEMPERATURE CYCLING

	Number of Cycles	
	5	
Step	Temperature (°C)	Time (Minutes)
1	$-55 \pm \frac{0}{3}$	60
2	$+25 \pm 10$	5 max
3	$+85 \pm \frac{3}{0}$	60
4	$+25 \pm 10$	5 max

4.4 Exposure Time at Temperature Extremes

The connector samples shall be subjected to the temperature extremes for the duration of Table 2. The duration of the test and length of exposure are standardized for a given mass of the test item. This approach allows the connector to reach thermal stability at the temperature of the test chamber while keeping the testing time to a minimum.

TABLE 2
EXPOSURE TIME AT TEMPERATURE EXTREMES

Mass of Specimen	Minimum Time
Above .136 kilograms, less than 1.36 kilograms	1 hour

5.

DOCUMENTATION

The data sheets shall contain:

- (A) Title of test, date and name of operator.
- (B) Sample description.
- (C) Test equipment used and date of latest calibration.
- (D) Test procedure
- (E) Values and observations
 - (1) Visual examination
 - (2) Monitoring measurements
 - (3) Insertion loss measurements including methods used.
 - (4) Assembly mass (see 4.2)
 - (5) Initial and final measurements (see 4.1)

HUMIDITY TEST PROCEDURE (Ref. EIA FOTP-5)

1. INTENT

- 1.1 The intent of this test is to permit evaluation of the properties of the materials used in fiber optic interconnecting devices as they are influenced or deteriorated by the effects of high humidity and heat conditions. It is an accelerated environmental test, accomplished by the continuous exposure of the specimen to high relative humidity at various temperatures.
- 1.2 Steady State Test
This test imposes a vapor pressure on the material under test that constitutes the force behind moisture migration and penetration. Hygroscopic materials are sensitive to moisture and deteriorate rapidly under humidity conditions. Absorption of moisture may result in swelling that would destroy functioning utility, and cause loss of physical strength and changes in other important mechanical properties. Degradation of optical and electrical properties may also occur. This test, while not necessarily intended as a simulated tropical test, is useful in determining moisture absorption of insulating materials.

2. TEST EQUIPMENT

2.1 Test Chamber

The test chamber and accessory shall be constructed and arranged in such a manner as to avoid condensate dripping on the test sample. The chamber shall be trap-vented to the atmosphere to prevent the build-up of total pressure. Relative humidity shall be determined from the dry bulb-wet bulb thermometer comparison method or an equivalent method approved by the procuring activity. When readout charts are used, they shall be capable of being read with a resolution within 0.6°C. When the wet bulb control method is used, the wet bulb and tank shall be cleaned and a new wick installed at least every 30 days. The air velocity flowing across the wet bulb shall be not less than 4.6 meters per second. Provisions shall be made for controlling the flow of air throughout the internal test chamber area where the velocity of air shall not exceed 0.8 meter per second. Steam or distilled, demineralized, or deionized water shall be used to obtain the specific humidity. No rust or corrosion contaminants shall be imposed on the sample by the test facility.

3. TEST SAMPLE DESCRIPTION

- 3.1 Sample. A test sample shall consist of a mated plug and receptacle.
- 3.2 Sample Preparation. The sample shall be prepared using the Galite S050 ST fiber optic cable.

4. TEST PROCEDURE

4.1 Test

4.1.1 Steady-State

4.1.1.1 Measurements.

The specimen shall be monitored for variations in attenuation all during the test.

4.1.1.2 Conditioning.

The specimen shall be conditioned in a dry oven at a temperature of $50 \pm 5^\circ\text{C}$ for a period of 24 hours. At the end of this period, measurements shall be made as specified.

4.1.1.3 Mounting

The specimen shall be mounted by the normal mounting means, in the normal mounting position, but shall be positioned so that it does not contact anything, and so that the entire specimen receives essentially the same degree of humidity.

4.1.1.4 Exposure

The specimen shall be placed in a chamber and subjected to a relative humidity of 90 to 95% and a temperature of $40 \pm 2^\circ\text{C}$ for the period of time of 96 hours.

4.2 Final Measurement

4.2.1 High Humidity

4.2.1.1 Monitoring

During the exposure period and while the specimens are still in the chamber, the attenuation monitoring shall be continued.

4.2.2 After High Humidity

Upon removal from the humidity chamber, the final measurements shall be made within 1 to 2 hours, ensuring return to equilibrium conditions.

5. DOCUMENTATION

Test data sheets shall contain:

- A. Title of test, date, and name of operator.
- B. Sample description - include fixturing.
- C. Test equipment used and date of latest calibration.
- D. Values and observations - initial and final ambient conditions.

SALT SPRAY (CORROSION) (Ref. EIA FOTP-16)

1. INTENT. The purpose of this test is to determine the effects of a controlled salt laden atmosphere on interconnecting device components, finishes and mechanisms. Typical effects of this test include:

- a. Exposure of base metals, pitting and porosity of finishes.
- b. Cracking and delamination of components and/or finishes.
- c. Abnormal nicks, cracks or scratches on finished surfaces that indicate the removal of the normal protective coating.

2. TEST EQUIPMENT

2.1 Chamber. The chamber and all accessories shall be made of material which will not affect the corrosiveness of the fog, such as glass, hard rubber, or plastic. Wood or plywood should not be used because they are resiniferous. Materials should not be used if they contain formaldehyde or phenol in their composition. In addition, all parts which come in contact with test sample shall be of materials that will not cause electrolytic corrosion. The chamber and accessories shall be constructed and arranged so that there is free circulation of the spray to the same degree for all samples, no return of the liquid that has come in contact with the test samples to the salt-solution reservoir, and no direct impinging of the spray or condensation dripping on the samples. The chamber shall be properly vented to prevent pressure build-up and allow uniform distribution of salt spray. The discharge end of the vent shall be protected from strong drafts which can cause strong air currents in the chamber.

2.2 Atomizers. The atomizer or atomizers used shall be of such design and construction as to produce a finely divided, wet, dense fog. Atomizing nozzle shall be made of material which does not react with the salt solution.

2.3 Air Supply. The compressed air entering the atomizers shall be free from all impurities such as oil and dirt. Means shall be provided to humidify and warm the compressed air as required to meet the operating conditions. The air pressure shall be suitable to produce a finely divided dense fog with the atomizer or atomizers used. To insure against clogging the atomizers by salt deposition, the air should have a relative humidity of 95 to 98 percent at the point of release from the nozzle. A satisfactory method is to pass the air in very fine bubbles through a tower containing heated water. The temperature of the water should be 35°C and often higher. The permissible temperature increases with increasing volume of air and with decreasing heat insulation of the chamber, and temperature of its surroundings. It should not exceed a value above which an excess of moisture is introduced into the chamber (for example 43.3°C) at an air pressure of 83 kilopascals, or a value which makes it impossible to meet the requirement for operating temperature.

2.4 Salt solution. The salt-solution concentration shall be 5 percent. The salt used shall be sodium chloride containing on the dry basis not more than 0.1 percent of sodium iodide, and not more than 0.5 percent of total impurities. The 5 percent solution shall be prepared by dissolving 5 ± 1 parts by weight of salt in 95 parts by weight of distilled or other water. Distilled or other water used in the preparation of solutions shall contain not more than 50 parts per million of total solids. The solution shall be kept free from solids by filtration using a noncorrosive filter similar to that shown on figure 1, and located in the salt solution reservoir in a manner such as that illustrated on figure 2. The solution shall be adjusted to and maintained at a specific gravity in accordance with figure 3. The pH shall be maintained between 6.5 and 7.2, when measured at a temperature between 33.9° and 36.1°C. Before adjusting the pH, gently boil a sample of the solution (e.g., 10 milliliters in a pyrex breaker) for 30 to 60 seconds to remove the CO₂ absorption, then cool to the specified temperature prior to measuring the sample solution pH. Only diluted chemically pure grade hydrochloric acid or sodium hydroxide shall be used to adjust the pH. The pH measurement shall be made electrometrically using a glass electrode with a saturated potassium-chloride bridge or by a colorimetric method such as bromothymol blue, provided the results are equivalent to those obtained with the electrometric method.

3. TEST SAMPLE.

3.1 Procedure.

3.1.1 Sample.

3.1.1.1 Connector. A test sample shall consist of a connector assembly complete with optical cables, terminations, sealing plugs and accessories. The sample shall be suspended in a horizontal position. The mounting shall be compatible with the requirements for locating samples in the chamber as outlined in the test procedure. The connector assembly shall be normally mated.

3.1.1.2 Preparation. Samples shall be given a minimum of handling, particularly on the significant surfaces, and shall be prepared for test immediately before exposure. Samples shall not be cleaned with solvent. A suitable coating of wax or similar substance impervious to moisture shall be applied to protect those portions of samples which come in contact with the support and to the cut edges and surfaces not required to be coated on coated samples.

4. TEST PROCEDURE.

4.1 Location of samples. Samples shall be suspended from the top using glass or plastic hooks, waxed twine, or string or nylon thread. If plastic hooks are used, they shall be fabricated of material, such as lucite, that is nonreactive to the salt solution. The use of metal hooks is not permitted.

4.2. Procedure. The test procedures shall be as follows:

4.2.1 Temperature. The test shall be conducted with a temperature in the exposure zone maintained at $35 \pm \begin{matrix} +1.1 \\ -1.7 \end{matrix} \text{°C}$. Satisfactory methods for controlling the temperature

accurately are by housing the apparatus in a properly controlled constant temperature room, thoroughly insulating the apparatus and preheating the air to the proper temperature prior to atomization, and jacketing the apparatus and controlling the temperature of the water or of the air used. The use of immersion heaters for the purpose of maintaining the temperature within the chamber is prohibited.

4.2.2 Atomization. The conditions maintained in all parts of the exposure zone shall be such that a suitable receptacle placed at any point in the exposure zone will collect from 0.5 to 3.0 milliliters of solution per hour for each 80 square centimeters of horizontal collecting area (10 centimeters diameter) based on an average run of at least 16 hours. The 5 percent solution collected shall have a sodium-chloride content of from 4 to 6 percent (specific gravity) in accordance with figure 3 when measured at a temperature between 33.9° and 36.1°C. At least two clean fog collecting receptacles shall be used, one placed near any nozzle and one place as far as possible from all nozzles. Receptacles shall be fastened so that they are not shielded by samples and so that no drops of solution from samples or other sources will be collected. The specific gravity and quantity of the solution collected shall be checked following each salt spray test. Suitable atomization has been obtained in boxes having a volume of less than 0.3 cubic meter with the following conditions:

- a. Nozzle pressure of from 83 to 124 kilopascals.
- b. Orifices of from 508 to 762 μm in diameter.
- c. Atomization of approximately 10 liters of the salt solution per cubic meter of box volume per 24 hours.

When using large size boxes having a volume considerably in excess of 0.3 cubic meter the conditions in 4.2.2 a, b and c may have to be modified in order to meet the requirements for operating conditions.

4.2.3 Length of test. The length of the salt spray test shall be 48 hours. The test shall be run continuously for the time indicated or until definite indication of failure is observed, with no interruption except for adjustment of the apparatus and inspection of the specimen.

4.2.4 Post cleaning. Immediately after exposure, the test samples shall be dipped in running tap water not warmer than 38°C for 5 minutes, maximum and dried for 12 hours, maximum in a circulating air oven at a temperature of 38° ± 3°C, after which the sample shall be examined at room temperature. If closer examination of a plated surface is required, the corrosion products may also be removed using any method that will not affect the plating.

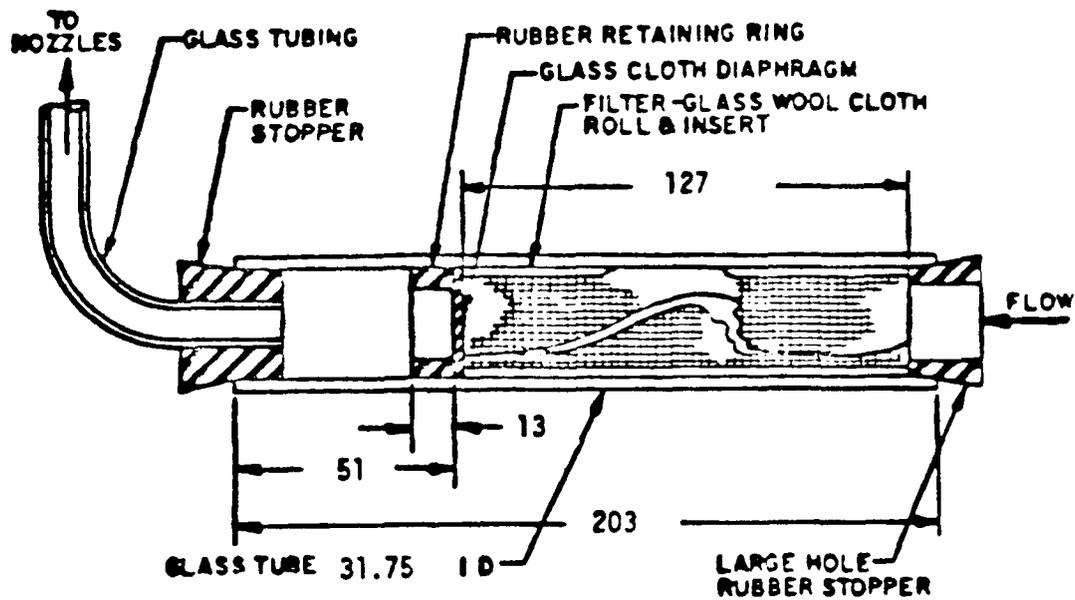
4.2.5 Measurements. At the completion of the exposure period, attenuation measurements shall be made. To aid in examination, samples shall be prepared in the following manner. Salt deposits shall be removed by a gentle wash or dip in running water not warmer than 38°C and a light brushing, if necessary, using a soft-hair brush or plastic-bristle brush.

4.2.6 Examination. Examination of the connector shall include the following.

- a. Exposure of base metals, pitting and porosity of finishes.
- b. Cracking and delamination of components and/or finishes.
- c. Abnormal nicks, cracks or scratches on finished surfaces that indicate the removal of the normal protective coating.

5. DOCUMENTATION. Data sheets shall contain:

- a. Title of test, date and name of operator.
- b. Sample description - including fixture.
- c. Test equipment used and date of latest calibration.
- d. Identification of test method.
- e. Values and observations:
 - (1) Visual examination (see 4.2.6).



NOTE: Dimensions in millimeters

FIGURE 1. Salt solution filter.

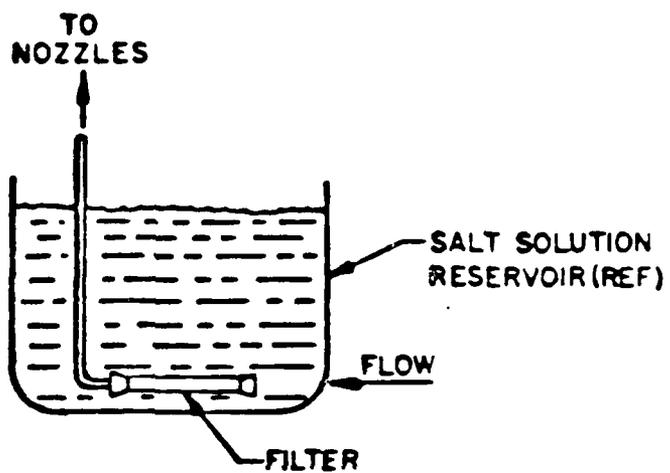


FIGURE 2. Location of salt solution filler.

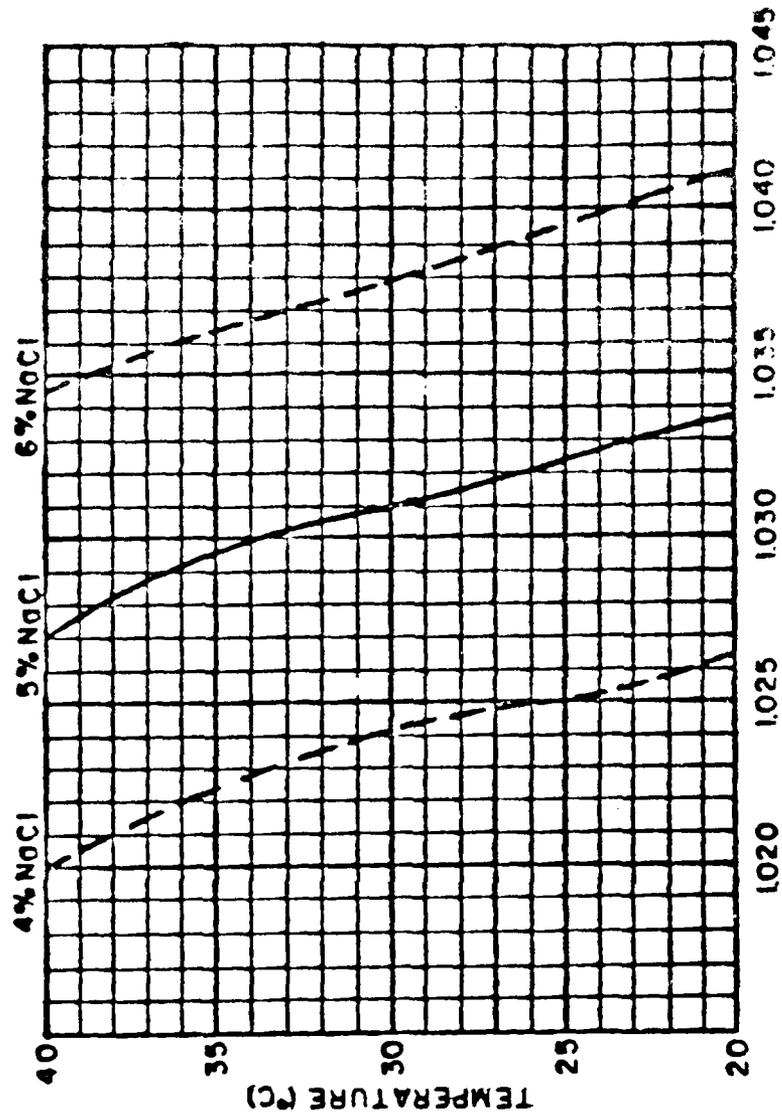


FIGURE 3. Variations of specific gravity of salt (NaCl) solutions with temperature.

AD-A137 597

DEVELOPMENT OF A FIBER OPTICS CONNECTOR BASED ON
MIL-C-38999 SERIES IV(U) G AND H TECHNOLOGY INC SANTA
MONICA CA D A PARKER 15 OCT 82 5000-82-0078
NAC-TR-2322 N00133-81-C-0062

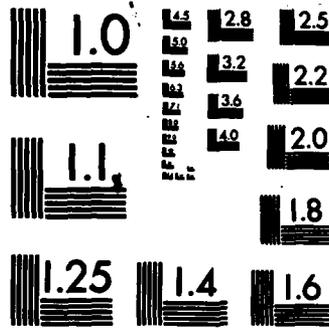
2/2

UNCLASSIFIED

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3
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1. INTENT

- 1.1 This test is intended to determine the ability of the fiber optic interconnecting device to withstand the effects of sand and dust exposure simulating worst conditions to which such an interconnecting device should ever be exposed.
- 1.2 Potential failure modes for this test include:
- A. Leakage of sand and dust contamination into the interconnecting device interface area causing attenuation of light transmission.
 - B. Damage to optical waveguide endfaces, degrading light transmission.
 - C. Leakage of sand and dust into the backshell of the interconnecting device introducing potential contamination when contacts are removed and re-inserted.
 - D. Cable seal damage.

2. TEST EQUIPMENT

2.1 Test chamber

The test shall be conducted in a suitable chamber which will expose the interconnecting device to sand and dust.

2.2 Fixturing

The clamping of the interconnecting device shall not prohibit the sand and dust from access to any part of the interconnecting device which has a seam, interface or clamping feature. The clamps shall not distort the specimen under test and shall hold the interconnecting device and fiber optic cable.

3. TEST SAMPLE

- 3.1 The test sample shall consist of an interconnecting device and a length of fiber optic cable secured in the interconnecting device by normal securing means.

4. TEST PROCEDURE

- 4.1 Test shall be conducted at room temperature.
- 4.2 Install the specimen into the fixturing in the test chamber.
- 4.3 Exposure to sand and dust shall be for the duration per FOTP 35 1/.

4. TEST PROCEDURE (CONTD.)

- 4.4 After exposure, sand and dust may be wiped from the exterior of the connector.
- 4.5 Insertion loss measurements shall be taken before (ref.) and after exposure to sand and dust.
- 4.6 Coupling forces shall be measured before and after exposure to sand and dust.
- 4.7 Inspect the optical waveguide endfaces for endface degradation. Inspect the backshell chamber for evidence of contamination.

5. DOCUMENTATION

Test data sheets shall contain the following:

- A. Title of test, date and name of operator.
- B. Identification of the interconnecting device and fiber optic cable.
- C. Test equipment used and date of latest calibration.
- D. Results of specified examination before and after exposure test.

1/ This FOTP will appear in a future addendum to EIA RS-455.

FIBER OPTIC CONNECTOR TEST

DUST (FINE SAND)

1. PURPOSE The dust test is used to ascertain the ability of fiber optic connectors to resist the effects of a dry dust (fine sand) laden atmosphere. This test simulates the effect of sharp edged dust (fine sand) particles, up to 150 microns in size, which may penetrate into cracks, crevices and joints. This test is applicable to all mechanical, electrical, electronic, optical, electrochemical, and electromechanical devices for which exposure to the effects of a dry dust (fine sand) laden atmosphere is anticipated. However, this method is not applicable to Southeast Asian dust conditions.

1.1 General Effects. General effects resulting from the penetration of dust can cause a variety of damage such as fouling moving parts, forming electrically conductive bridges with resulting shorts and acting as a nucleus for the collection of water vapor, and hence a source of possible corrosion and malfunction of equipment.

2. APPARATUS. The test facility shall consist of a chamber and accessories to control dust concentration, velocity, temperature, and humidity of dust laden air. In order to provide adequate circulation of the dust laden air, no more than 50 percent of the cross-sectional area (normal to air flow) and 30 percent of the volume of the chamber shall be occupied by the test item(s). The chamber shall be provided with a suitable means of maintaining and verifying the dust concentration in circulation. A minimum acceptable means for doing this is by use of a properly calibrated smoke meter and standard light source. The dust laden air shall be introduced into the test space in such a manner as to allow it to become approximately laminar in flow before it strikes the test item.

2.1 Dust Requirements. The dust used in this test shall be a fine sand (97-99 percent by weight S10) of angular structure, and shall have the following size distribution as determined by weight, using the U.S. Standard Sieve Series:

- a. 100 percent of this dust shall pass through a 100-mesh screen.
- b. 98±2 percent of the dust shall pass through a 140-mesh screen.
- c. 90±2 percent of the dust shall pass through a 200-mesh screen.
- d. 75±2 percent of the dust shall pass through a 325-mesh screen.

NOTE: 140-mesh silica flour as produced by the Ottawa Silica Company, Ottawa, Illinois, or equal, is satisfactory for use in the performance of these tests.

3. PROCEDURE.

3.1 Procedure I. Prepare the test item in accordance with General Requirements 3.2, positioning the test item as near the center of the chamber as practicable. If more than one item is being tested, there shall be a minimum clearance of 4 inches between surfaces of test items or any other material or object capable of furnishing protection. Also, no surface of the test item shall be closer than 4 inches from any wall of the test chamber. Orient the item so as to expose the most critical or vulnerable parts to the dust stream. The test item orientation may be changed during the test if so required by the equipment specification.

Step 1 - Set the chamber controls to maintain an internal chamber temperature of 23°C (73°F) and a relative humidity of less than 22 percent. Adjust the air velocity to 1,750±250 feet per minute. Adjust the dust feeder to control the dust concentration at 0.3±0.2 grams per cubic foot. With the test item nonoperating, maintain these conditions for 6 hours.

Step 2 - Stop the dust feed and reduce the air velocity to 300±200 feet per minute. Raise the internal chamber air temperature to 63°C (145°F). Hold these conditions 16 hours.

Step 3 - While holding chamber temperature at 63°C (145°F) adjust the air velocity to 1,750±250 fpm. Adjust the dust feeder to control the dust concentration at 0.3±0.2 gms per cubic foot. Unless otherwise specified, with the test item non-operating, maintain these conditions for 6 hours.

Step 4 - Turn off all chamber controls and allow the test item to return to standard ambient conditions. Remove accumulated dust from the test item by brushing, wiping, or shaking, care being taken to avoid introduction of additional dust into the test item. Dust shall not be removed by either air blast or vacuum cleaning.

Step 5 - Operate and inspect the test item in accordance with General Requirements, 3.2.

Step 6 - Inspect the test item and obtain results as specified in General Requirements, 3.2.4. In the performance of this inspection, test items containing bearings, grease seals, lubricants, et cetera, shall be carefully examined for the presence of dust deposits.

4. SUMMARY. The following details shall be as specified in the Detail specification:

- a. Pretest data required.
- b. Failure criteria.

4. SUMMARY. (Cont'd.)

- c. Change in orientation during test if required.
- d. Whether equipment is to operate during test and length of time required for operation and measurements (see Steps 1 and 3).
- e. Whether the second 6-hour test at 63°C (145°F) shall be performed immediately after reaching stabilization (See Step 2).
- f. Temperatures for Steps 2 and 3, if different from 63°C (145°F).

VIBRATION TEST PROCEDURE

1. INTENT

- 1.1 The intent of this test is to determine the effects of vibration within the sinusoidal and random vibration environments that may be encountered during the life of the fiber optic connector. Typical indications of damage resulting from this test are:

Inability to mate or unmate, broken parts or accessories, transmission loss, damage to seals.

2. TEST EQUIPMENT

- 2.1 The vibration system consisting of the vibration machine together with its auxiliary test equipment, shall be capable of generating either a sinusoidal or random excitation. Test equipment for random vibration shall produce random excitation that possesses a gaussian (normal) amplitude distribution, except that the acceleration magnitudes of the peak values may be limited to a minimum of three times the rms (three-sigma [σ] limits).

3. TEST SAMPLE

3.1 Type of Sample

A vibration test sample shall be defined as a fully terminated connector and associated hardware. One sample shall be tested per 4.1. and one per 4.2.

3.2 Preparation

Each test sample shall be prepared with wave guide and other materials or processes, simulating field usage of the connector. Only normal locking means shall be used. Test samples shall be visually examined for chips, cracks, tears, loose or missing parts, proper lubrication, proper assembly and mate-ability. The test sample shall be terminated with 140 micron Galite 5050 ST graded index glass fibers.

3.3 Method of Mounting

The connector test specimen shall be attached to a fixture capable of transmitting the vibration conditions specified. The test fixture shall be designed such that resonant vibration inherent in the fixture within the frequency range specified shall be minor.

3.3 Method of Mounting (Contd..)

The magnitude of the applied vibration shall be monitored on the test fixture near the specimen mounting points. The test specimen shall be mounted rigidly to the test fixture and simulate as closely as possible the normal mounting of the connector. A minimum of 7.874 inches (20 centimeters) of fiber optic cable shall be unsupported on both ends of the connector and attached to the vibrating surface. One of the vibration-test directions shall be parallel to the mounting surface of the bracket. Vibration input shall be monitored on the mounting fixture in the proximity of the support point of the specimen. The plug shall have an accessory load fixture in accordance with Figure 3 attached during vibration.

4. TEST PROCEDURES

The connector shall be continuously monitored for all attenuation increases before, during and after the test.

4.1 Test Conditions (Sinusoidal Vibration)

4.1.1 Sinusoidal Vibration Conditions

Vibration conditions shall be in accordance with Table 1 and Figure 1, as applicable.

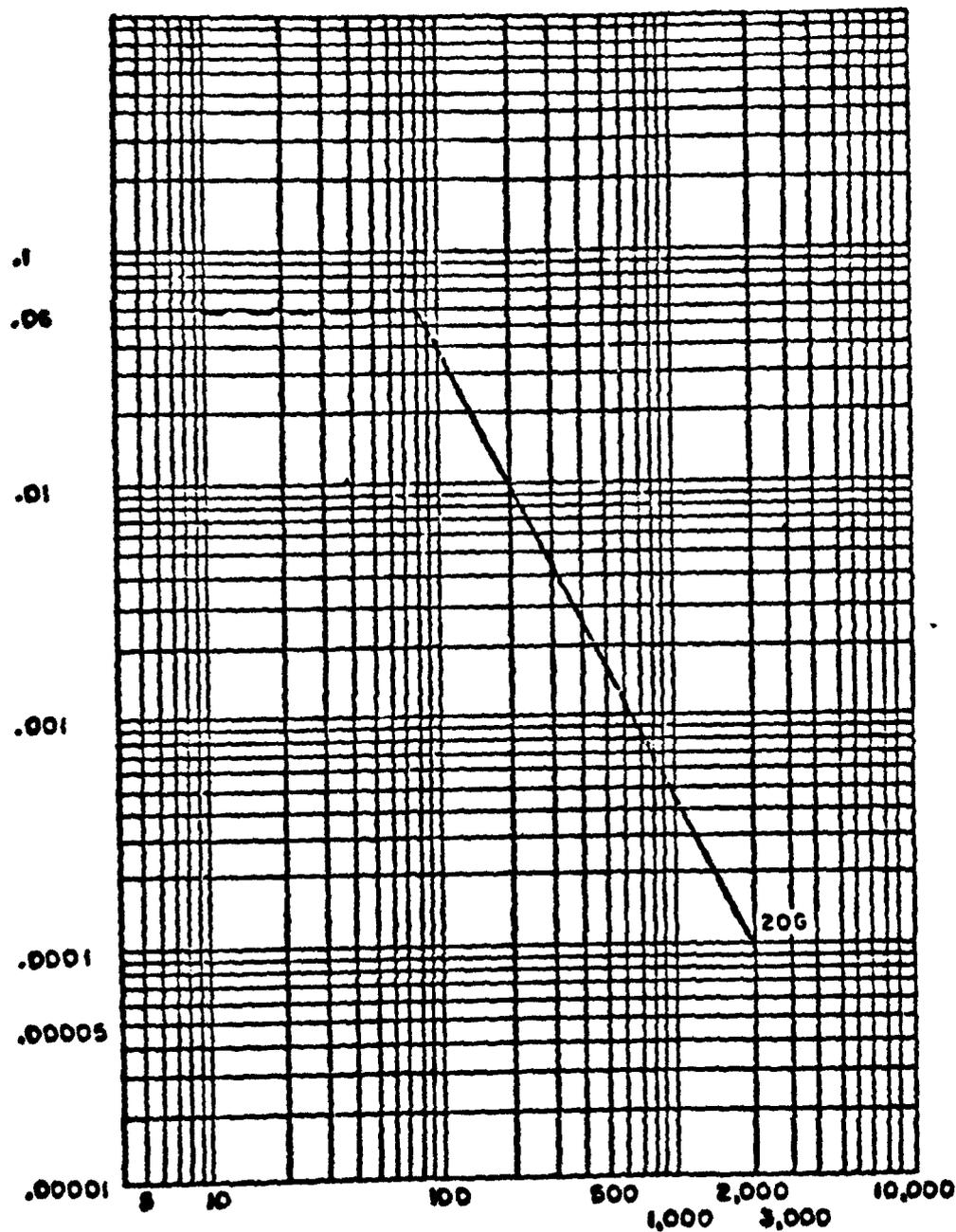
TABLE 1
VIBRATION CONDITIONS

Frequency Range	Peak g level
High - 10 to 2,000	20

4.1.2 Resonance

A critical resonant frequency is that frequency at which any point on the specimen is observed to have a maximum amplitude more than twice that of the support points. When specified, resonant frequencies shall be determined either by monitoring parameters such as terminus separation, or by use of resonance-detecting instrumentation.

VIBRATION AM PLITUDE (DOUBLE AMPLITUDE-INCH)



VIBRATION FREQUENCY (Hz)

$$G = .0512f^2 DA \quad (f^2 = \text{frequency in hertz, } DA = \text{double amplitude in inches.})$$

FIGURE 1

Vibration Test Curve - High Frequency

4. TEST PROCEDURES (contd.)

4.1.3 Test Condition I (20g peak)

The specimens, while deenergized or operating under the load conditions specified, shall be subjected to the vibration amplitude, frequency range, and duration specified in 4.1.6.1, 4.1.6.2, and 4.1.6.3, respectively (see Figure 1).

4.1.3.1 Amplitude

The specimens shall be subjected to a simple harmonic motion having an amplitude of either .060 inches (1.52 mm) double amplitude (maximum total excursion) or 20g (peak), whichever is less. The tolerance on vibration amplitude shall be $\pm 10\%$.

4.1.3.2 Frequency Range

The vibration frequency shall be varied logarithmically between the approximate limits of 10 to 2,000 Hz.

4.1.3.3 Sweep Time and Duration

The entire frequency range of 10 to 2,000 Hz and return to 10 Hz shall be traversed in 20 minutes. This cycle shall be performed 12 times in each three mutually perpendicular directions (total of 36 times), so that the motion shall be applied for a total period of approximately 12 hours. Interruptions are permitted provided the requirements for rate of change and test duration are met. Completion of cycling within any separate band is permissible before going to the next band. When the procedure (see 4.1.3) of this Standard is used for the 10 to 55 Hz band, the duration of this portion shall be the same as the duration for this band using logarithmic cycling (approximately 1-1/3 hours in each of three mutually perpendicular directions).

4.2 Test Conditions (Random Vibration)

4.2.1 Control and Analysis of Random Vibration

4.2.1.1 Spectral-Density Curves

The output of the vibration machine shall be presented graphically as power-spectral density versus frequency. (1/) The spectral-density values shall be within +40 and -30% (± 1.5 dB) of the specified values between 10 Hz and 1,000 Hz, and within +100 and -50% (± 3 dB) of the specified values between 1,000 Hz and 2,000 Hz. A Filter bandwidth will be a maximum of 1/3-octave or a frequency of 25 Hz, whichever is greater.

1/ Power-spectral density is the mean square value of oscillation passed by a narrow-band filter per unit-filter bandwidth. For this application it is expressed as G^2/f where G^2/f is the mean-square value of acceleration expressed in gravitational units per number of cycles of filter bandwidth. The spectral-density curves are usually plotted either on a logarithmic scale, or in units of decibels plotted either on a logarithmic scale, or in units of decibels (dB). The number of decibels is defined by the equation:

$$\text{dB} = 10 \log \left[\frac{G^2/f}{G_r^2/f} \right] = 20 \log \left[\frac{G/\sqrt{f}}{G_r/\sqrt{f}} \right]$$

The rms value of acceleration within a frequency band between f_1 and f_2 is:

$$\text{Grms} = \left[\int_{f_1}^{f_2} \left(\frac{G^2}{f} \right) df \right]^{1/2}$$

where G_r^2/f is a given reference value of power-spectral density, usually the maximum specified value.

4.2.1.2 Distribution Curves

A probability density-distribution curve may be obtained and compared with a gaussian-distribution curve. The experimentally obtained curve shall not differ from the gaussian curve by more than $\pm 10\%$ of the maximum value

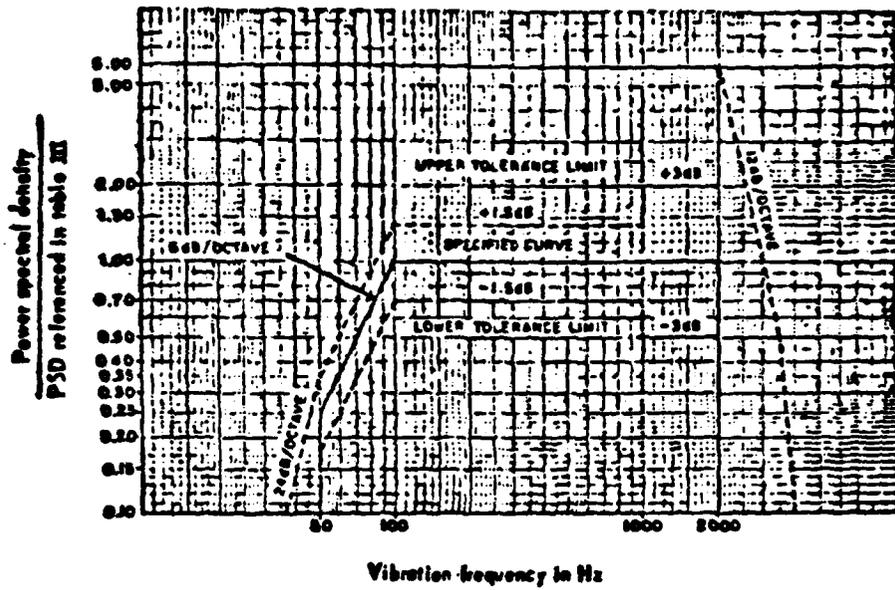


TABLE III. Values for test-condition II 1/

Characteristics	
Power spectral density	Overall rms G
1.0	41.7

1/ For duration of test, see 4.2.2

FIGURE 2. Test condition II, random vibration test-curve envelope
(see table III).

4. TEST PROCEDURES (Contd.)

4.2.1.3 Vibration Input

The vibration magnitude shall be monitored on a vibration machine, on mounting fixtures, at locations that are as near as practical to the test-item mounting points. When the vibration input is measured, the minimum input vibration shall be made to correspond to the test curve (see Figure 2). Acceleration in the transverse direction, measured at the test-item attachment point, shall be limited to 100% of the applied vibration. The test point shall be the normal mounting means of the connector.

4.2.2 Procedure

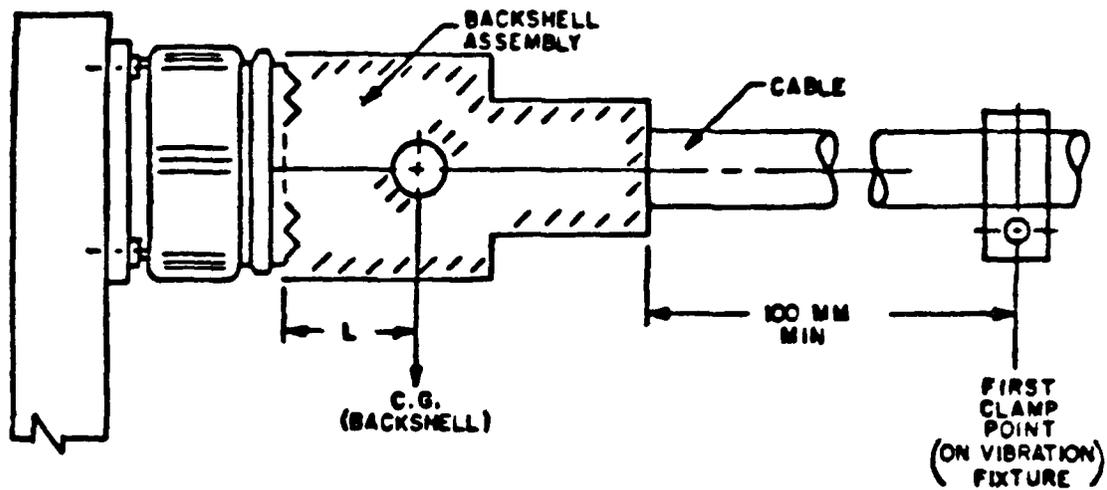
The specimen, or substitute equivalent mass, shall be mounted in accordance with 3.3 and the monitoring equipment attached, if applicable, in accordance with 4.2.1.3. The vibration machine shall then be operated and equalized or compensated to deliver the required frequencies and intensities conforming to the curves specified in Test Condition II, Figure 2. The specimen shall then be subjected to the vibration specified (see Table II) for the duration as specified: 8 hours, in the longitudinal direction and in a perpendicular direction for a total of 16 hours. Attenuation measurements shall be monitored before, during and immediately after the vibration testing.

Following the test, inspect each fiber end for end face condition and for end face location relative to the contact alignment rods.

5. DOCUMENTATION

5.1 Data sheets shall contain:

- A. Title of test, date, and names of personnel.
- B. Sample description - include fixture.
- C. Test equipment used and date of latest calibration.
- D. Test procedure.
- E. Values and observations.



Shell Size	L (MM) Root to C.G.	Wt. (KG) Backshell Assembly
9	15.24	.05
11	17.78	.06
13	19.05	.07
15	19.05	.09
17	19.05	.11
19	22.86	.18
21	22.86	.22
23	23.37	.25
25	23.37	.31

NOTES:

1. The standard strain relief may be replaced by a strain relief whose center for the mounting hole is located the same distance from the root of the serrations on the plug shell as the applied load. The standard bars may be replaced with bars whose weight equals the applied load less the cable weight, less the difference in weight between the longer strain relief and the standard strain relief and less clamp bars.
2. Dimensions are in millimeters.

FIGURE 3. Vibration test accessory.

DURABILITY TEST PROCEDURE (Ref. EIA FOTP-21)

1. INTENT

- 1.1 The intent of this test is to determine the effects of mating and unmating of the fiber optic connector in optical transmission degradation and in mechanical connector characteristics. By repeating the mating and unmating cycles to the worst probable cycling conditions, the durability of the connector is shown.
- 1.2 Typical resulting damage or degradation from this test may include:
- A. Inability to mate or unmate.
 - B. Broken parts or accessories.
 - C. Damage to seals.
 - D. Optical degradation through misalignment, etc.
 - E. Excessive wear causing optical degradation through particulate contamination.
 - F. Failure of fiber - terminus joint.

2. TEST EQUIPMENT

- 2.1 A test device shall be required to:
- 2.1.1 Mate and unmate the connector so that the plug and receptacle are completely separated during each cycle.
 - 2.1.2 Provide for constant speed mating and unmating at a rate of 300 cycles per hour maximum.
 - 2.1.3 A gage to measure the force being exerted between the interconnecting plug and receptacle connector halves.
 - 2.1.4 Attenuation monitoring equipment to measure light transmission during the testing.

3. TEST SAMPLE

- 3.1 A test sample shall consist of an interconnecting fiber optic device and a length of fiber optic cable secured in the interconnecting device by normal securing means. Loose cable ends must have fibers prepared with optically cleaved or polished end faces ready for attenuation monitoring during testing.

4. TEST PROCEDURE

- 4.1 The test sample shall be mounted in the test fixture with cable ends attached to attenuation measuring equipment. The sample shall be clamped to the fixture so that the connector will completely mate and completely separate during each test cycle.
- 4.2 Attenuation shall be monitored before, during and after the total number of cycles is applied.
- 4.3 The test cycle shall consist of completely mating and unmating the connector for 500 cycles at a rate of 300 cycles per hour, maximum.
- 4.4 Upon completion of the 500 cycles, measure final connector insertion loss and remove the connector from the fixture to visually examine the contacts and connector for degradation. Inspect the fiber ends in the contacts for end face condition and for end face location relative to the contact alignment rods.

5. DOCUMENTATION

Test data sheets shall contain:

- A. Title of test date and name of operator.
- B. Identification of the interconnecting device and fiber optic cable.
- C. Test equipment used and date of latest calibration.
- D. Record of attenuation monitoring before, during and after testing.
- E. Results of the specified examinations during and after loading.

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